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HYDROLOGIC STUDIES IN COACHELLA VALLEY, CALIFORNIA

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INTRODUCTION

Present irrigated agriculture in Coachella Valley, a part of the Colorado Desert, is based upon utilization of the ground water. For a number of years the U.S. Bureau of Reclamation, in contractual agreement with the Coachella Valley County Water District, has been in the process of bringing in a supplemental water supply from the Colorado River through the All-American Canal System. This new supply will cause an expansion of agriculture in the Valley. It will also change the character of such reclamation problems as drainage, irrigation practices, suitability of various soils for irrigation, and the chemical nature of some ground waters.

To develop fully the Valley's resources requires both a knowledge of its hydrology before importation of Colorado water and a continuing study of the changes wrought by that importation. In 1936 it was found that, while a number of studies of the Valley had been made (1, 3, 10, 11, 12)*, none contained a detailed hydrologic picture, particularly with relation to the quality of the water and the reclamation of saline soils. The study reported herein was therefore begun the following year.

In this study the quality of surface waters recharging the ground water basin was investigated, and the meager information on the quantitative flow of such surface waters was summarized and evaluated. An intensive survey was made of the quality of the ground water throughout the Valley, and peculiarities found were studied as to their cause and effect. Information on ground water levels was extended, interpreted, and summarized. Finally, the feasibility of reclaiming the saline soils which are found in parts of the Valley was investigated.

The cooperation of the Coachella Valley County Water District, the U.S. Department of Agriculture, Division of Irrigation Agriculture, and many farmers and well drillers was very helpful. Their assistance is gratefully acknowledged.

Interpretation of the practical agricultural implications of these data are not fully presented here. Such interpretations, along with recommendations on irrigation practices, can be obtained through the Agricultural Extension Service.

SUMMARY AND CONCLUSIONS

Water Quality

Perennial surface streams draining into the Valley, and the predominant ground waters, have a characteristic low salt content.

The percentage of sodium, as of total cations, in the ground water increases down the Valley, but the amounts of the total dissolved constituents do not similarly increase. In the lower valley trough, sodium percentages reach an observed maximum of 96, increasing from a minimum of 21 in the upper valley.

Where irrigation water with a high sodium percentage is used, the soil structure is impaired, and rates of water entry into the soil are decreased, often creating irrigation and reclamation difficulties. In the long run the effect of high sodium percentage will be greatest on fine-textured soils and least on coarse sands, but it will be noted more quickly on the coarse-textured soil.

Magnesium content of the ground waters decreases down the Valley. These data indicate the possibility of a magnesium deficiency for certain crops, but investigation of that point did not come within the scope of this study.

Not all ground waters of the Valley have a low salt content. A number of wells contain waters of a moderate to high salt content, but such waters normally do not have a high sodium percentage. In general, the waters of moderate to high salt content were found in the following areas:

1. The Garnet-Seven Palms Valley region.
2. Along the northeast edge of the Valley near a region where faults are known to exist.
3. Some relatively shallow wells in the central trough of the Valley which are probably affected by return waters from irrigated lands.
4. Shallow waters in the Indian Wells district.
5. An area at the lower end of the Mecca Canyon alluvial fan.
6. Oasis and South Salton regions below the Martinez Canyon alluvial fan.

In the Indian Wells district, particularly the more shallow wells yield water of surprisingly high nitrate content. Evidence indicates that the area was at one time covered with extensive mesquite forests. Under natural conditions there was not enough moisture to permit decomposition of the leaves and twigs, so large amounts of litter, high in nitrogen content, accumulated under the trees. When the lands were levelled and irrigated, the organic matter decomposed and the nitrates appear to have leached downward into the ground water. The nitrate content of the water fluctuates, and generally appears to be decreasing in amount.

Ground Water Levels

In the past, estimates have been made of the "safe yield" of Coachella ground water--the rate at which it can be pumped throughout the Valley without exceeding the supply. It is our opinion that there are not sufficient data available to make an accurate estimate of safe yield. Certainly the supply appeared to be adequate for the irrigated area of the period 1936-39, and could possibly be adequate, with careful use, for a greater area. During that period withdrawal from wells appears to have been about

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100,000 acre-feet a year. Some farmers will and have experienced localized difficulties in obtaining enough water because of interference of wells, or because of flow restrictions due to faulting along the sides of the Valley.

Increasing development of the Valley, with increasing demands for water, causes a progressive drop in water levels. The ground water can be visualized as a percolating body of water moving from the mountains to the lower trough, where, under natural conditions, it was lost by evaporation from the soil, transpiration from native plants, and seepage to Salton Sea. When water is withdrawn from wells for irrigation, the water level downstream is lowered, thus reducing these natural losses. The data indicate that water levels upstream from the irrigated areas have been little affected by downstream pumping.

Despite great seasonal fluctuations in recharge from surface streams, the main seasonal changes in ground water levels are those caused by pumping. This relative stability is indicated by the fact that no appreciable changes in water level appear in wells upstream from irrigated areas, and is due to the combined effect of a low rate of ground water movement and large underground storage. Apparently only a long cycle of wet or dry years would significantly affect the supply.

Lowering water levels cause an increase in cost because of the greater distance the water must be lifted. Also, increased capital outlays may become necessary to lower pump bowls, etc. However, there appears to be considerable opportunity to cut down waste and to increase pumping load factor, i.e., smaller pumps could be kept running more hours per year through use of regulating reservoirs, irrigation practices could be revised, pumping plants could be operated by a group or by a Water District.

If, upon the utilization of Colorado River water, all pumping of native water were to cease, a marked rise in water levels would occur. The area in the lower trough required for natural discharge (by seepage, evaporation, and transpiration) of the ground water flow would increase. Such an area would have a water table very close to the surface. However, plans for development will certainly include consideration of this problem, and there is no reason to believe a marked rise will occur, if pumping of Valley water is continued and the drainage program is adequate.

Reclamation

Most of the soluble salts in the more permeable saline soils are near the soil surface, and can be removed by leaching and flushing with water.

Flooding with local water of low salt content, but high sodium percentage, causes a marked movement of salt through the soil profile of most Valley soils. In some instances this may be hindered by stratification, but relief may be obtained by deep plowing or subsoiling where such strata are close enough to the surface to be so broken. Also, lateral drainage may occur above such strata.

By flushing water over the surface of saline soils for a short interval prior to leaching, large quantities of surface salts may be removed without passing through the soil profile. Although the effective period is of short duration, this method can be repeated with good results whenever salts accumulate at the surface of the soil. When borderline saline soils are under regular irrigation, it is good practice to flush the first water over the soil, and waste it from the lower ends of the irrigation system.

The data indicate that when local water is used on some soils in the lower trough of the Valley, infiltration rates are too low to maintain a low salt balance in the soil under normal irrigation and cropping programs. This effect is exaggerated in the studies reported here, because the soil was kept continuously wet. Under normal irrigation, the soil's dryness before each application would result in increased infiltration rates. Nevertheless, it would be difficult to maintain a thrifty cropping program with local water on many of the soils now saline.

Colorado River water, with a favorable sodium percentage and moderately high salt content, should have a better rate of entry into the soil. Less sodium means better soil structure, and the higher salt content makes it improbable, with free drainage, that composition of the soil water could be altered enough to become detrimental in any way to soil structure. Laboratory studies have shown an improvement in permeability where Colorado River water was compared with local high sodium percentage water, although these experiments do not bring out the maximum benefits that might be evident after soils go through wetting and drying cycles.

It is believed that most of the Coachella Valley saline soils can be reclaimed with Colorado River water, provided the water table is kept at a reasonable depth. This statement does not apply to Indio clay or Woodrow series soils, which should be considered unsatisfactory until, and if, experimental evidence is accumulated to the contrary.

As previously stated, extensive importation of water will produce excessively high water tables unless protective measures are taken. Drainage is therefore a necessary part of any irrigation development program for the Valley, but should not be a barrier to successful agriculture.

Ground water flow appears to be predominantly a lateral movement in discontinuous strata somewhat parallel to the surface topography. This factor suggests that the interception principle of artificial drainage can be employed.

It can be expected that there will be localized temporary perched water tables here and there throughout the irrigated areas, as there are at present. These have caused crop injury, although not contributing greatly to salinity.

GENERAL FEATURES OF THE VALLEY

Geography and Physiography

Coachella Valley, a triangular-shaped graben, lies at the northwestern end of the Colorado Desert, in the south central part of Riverside County, California. It is bounded on the west and north by high mountain ranges, on the eastern side by badly broken Tertiary sedimentary deposits (locally known as the Mud Hills), and on the south and southeast by Salton Sink. The valley proper varies in elevation from 245 feet below to about 500 feet above sea level. While the origin of this valley is generally ascribed to block faulting, there is a lack of agreement regarding the sequence of geologic events

Blake (2) , Mendenhall (10), and Brown (3) contend that in a period that is geologically very recent Salton Basin was an extension of the Gulf of California, and that it was isolated from the latter by building of the Colorado River delta. The Colorado River then discharged to the north forming Lake Cahuilla, a fresh water lake with a surface elevation some 40 feet above sea level. In time the Colorado River shifted its course to the south, leaving the lake to disappear through evaporation.

Free (6) and Buwalda (4) contend that the present Salton Sink was never an arm of the sea but rather that it has settled as a block between two fault lines in such a way as to exclude the entrance of the sea.

The present Salton Sea has been in existence since 1905, when the Colorado River breached its levees and flowed into Salton Sink until February, 1907. Since then a sea has been maintained by drainage and spill water from Imperial Irrigation District in Imperial Valley.

Old settlers reported that large quantities of flood waters from the Colorado River entered Salton Sink in 1840, 1849, 1852, 1859, 1862, and 1867. The amount entering in 1862 was said to have been extremely large (5). This water must have evaporated within a few years for King (8), in describing a trip through the Valley in May, 1866, makes no reference to a large body of water.

Climate

United States Weather Bureau records for Indio, which extend over a period of about 60 years, indicate a mean annual rainfall of 3 inches, a portion often coming from summer thunder storms, and a mean average temperature of 73°F. The highest recorded temperature for this station is 125°F., the lowest 16°F.

Water supply

Whitewater River, which rises on Mt. San Gorgonio, traverses the main axis of the Valley and empties into Salton Sea. Table 1 lists the watersheds. Of these, the San Bernardino and the San Jacinto mountain groups form the important streams. Although the watershed has an area of about 1200 square miles, the mean annual discharge is not large, since the greater part of the shed is desert. Only during flood stage does surface water reach Salton Sea, as the normal flow quickly enters the highly permeable alluvial fans. In fact, with the exception of a small area in and above Palm Springs, all irrigation water in Coachella Valley is now obtained from wells.

Measurements of the amounts of water entering Coachella Valley are very deficient. The U. S. Geological Survey made a few isolated readings at the end of the last century, and for a number of years the Coachella Valley County Water District made measurements on eleven streams discharging into the Valley. Unfortunately these measurements were made intermittently. As it is not feasible to reach most of the stations during flood period, when the run-off during a few days might exceed the combined run-off for the remainder of the year, the figures given do not truly represent total flow. They do indicate that the flow varies widely from year to year, and that the highest sustained run-off occurs during April. Whitewater River, Snow, and Tahquitz Creeks are perennial streams from their source to the edge of the Valley.

TABLE I.

WATERSHEDS OF COACHELLA VALLEY

Name	Approx. area * in sq. miles	Approx. range in elevation. Ft. above sea level
Little San Bernardino M't'n group	430	not known
San Bernardino M't'n group	296	1400-11485
Morongo Canyon group	100	1400-8966
Mission Creek	46	2500-9500
Whitewater River	62	1400-11485
Cottonwood-Stubby-Lyon group	22	1800-6607
Millard Canyon	16	2500-7700
Hathaway-Potrero group	22	2500-7900
San Gorgonio River	28	2600-9300
San Jacinto M't'n group	135	800-10805
Banning-Cabazon group	40	1500-7800
Snow-Falls group	23	1250-10805
Chino Canyon group	18	900-10805
Tahquitz Canyon	20	500-10600
Andreas group	14	800-8400
Murray Canyon	10	800-8900
West Palm Canyon	10	800-7600
Santa Rosa M't'n group	335	100-8705
Palm Canyon	92	800-8046
Cathedral-Magnesia group	18	400-3000
Deep Canyon group	65	500-8705
Guadalupe-Toro group	48	100-6539
Martinez-Agua Alta group	52	600-8705
Barton Canyon group	60	500-6650

* Data are principally from Tait (12)

Date palms arch over irrigation waters in Coachella Valley.
(credit: U. S. Bureau of Reclamation)

FLOW OF 11 STREAMS ENTERING COACHELLA VALLEY*

In Cubic Feet Per Second

	1936	1937	1938
January	---	---	---
February	---	---	64
March	55	---	---
April	118	---	305
May	82	---	---
June	66	194	242
July	51	---	---
August	53	101	103
September	44	---	---
October	46	68	94
November	---	---	---
December	---	67	---

*On basis of one measurement per stream, usually made near the beginning of the month of the record. Measurements not made during flood.

Soils

During 1923, Kocher and Harper (9) made a soil survey of the major portions of the potential agricultural land in Coachella Valley, an area embracing 220,160 acres. Of the area surveyed, about one fourth is composed of Coachella soils, one fourth Indio, and approximately one fourth Superstition soils, the remainder being made up of rough, broken land, Woodrow soil, and dune sand. The Coachella and Superstition soils are light gray in color, relatively coarse textured, calcareous throughout the soil profile, and often wind-blown. The former has been derived from igneous rocks high in quartz, the latter from rocks of mixed origin. Agriculturally the Coachella series is better than the Superstition, since most of the latter is extremely coarse.

The Indio series is represented by recent alluvial brownish-gray soils derived from igneous rocks high in quartz. In general, these soils are finer textured than the Coachella series, because they have been deposited farther down the slope where the grade is flatter. The finer textured soils of this series are located in the trough of the Valley, and often contain large amounts of salines.

The Woodrow series, lake-laid soils, are confined to the area between the present beach line of Salton Sea and that of 1907, when the present sea was at its maximum height. These are heavy-textured saline soils of mixed origin.

The soil survey report (9) contains an "alkali" map. It shows that much of the land in the original zone of flowing wells is strongly saline.

Generally speaking, all the soils are highly micaceous, with a resultant predominance of flat elongated soil particles. The soils do not tend to pack unduly, even under use of heavy grading and cultivating equipment. Often they have extremely low volume weights, and in fills tend to bulk excessively until wet down.

A remarkable amount of small fresh-water shells are found throughout most of the soils, but these shells decompose very slowly.

Development of Coachella Valley

A railroad line was completed through Coachella Valley by the Southern Pacific Company in 1879. Under the terms of the agreement between the railroad and the Federal Government every other section of land throughout the Valley became the property of the railroad. A greater part of the non-railroad land was filed upon during 1885 and 1886 under the provisions of the Desert Act. However, it was not developed at that time.

In 1894 the railroad company drilled a deep well at Mecca (then known as Walters), proving the presence of an abundant supply of good quality artesian water. It was not until 1900, however, that well drilling in this Valley was successful. At that time a hydraulic well drilling rig was employed to drill a well at Indio. The result was so favorable, 500 feet of well being drilled in 7 hours, that by 1907, (10) there were about 400 wells in the region between Indio and Salton Sea, about three quarters of which were flowing. Mendenhall (10) reports that in 1905 the zone of flowing wells extended as far up the Valley as Indio.

Agriculture has gradually moved up the Valley away from the fine textured, saline soils. At present many of the original farms have been abandoned.

A crop survey made jointly by the Coachella Valley County Water District and the University of California in 1936-37 showed the following acreages: alfalfa, 1496, cotton 1460, citrus 2461, dates 2644, citrus and dates 552, figs 48, truck crops 3655, table grapes 2280, pecans 46, pasture 901, total 15,543 (11).

WATER QUALITY

In these studies samples of both surface and ground water were examined, but the emphasis was placed on ground water because present irrigation in the Valley is almost exclusively by wells, and because chemical composition of ground water might indicate the nature of ground water movement.

Chemical Characteristics of Surface Waters

The chemical composition of water samples collected mainly in April, 1937, and June, 1938, from the principal surface streams draining into Coachella Valley is shown in Table 2. The approximate flow observed when the samples were collected is also given. These figures are not a good indication of the yield of the watersheds because of wide fluctuation in flow and extreme variation, from stream to stream, in infiltration above point of sampling.

Using the limited run-off data as a means of weighting electrical conductivity values for each stream, the mean conductivity for all surface streams appears to be approximately 320 micromhos/cm at 25°C.*

* Electrical conductivity of irrigation waters was previously commonly reported as K x 10/ at 25° C. Data reported on the old basis can be converted to the new standard by multiplying by 10.

Chemical Characteristics of Ground Waters

Chemical analyses of 118 wells and 2 springs in the Coachella Valley area, together with such pertinent hydrological data on the particular wells as it was possible to obtain, are presented in Table 3. On an average, about one-fifth of all wells in the Valley were tested. In districts where unusual chemical characteristics prevailed, such as in the Indian Wells and Oasis areas, a considerably higher per cent of all wells was tested, while in areas of more uniformity the percentage was smaller. On the whole, the data are representative of all known ground water conditions in the Valley.

The information on well depth and perforations was obtained mainly from well drillers, farm operators, and any other sources available. For various reasons such data are not always accurate, but sufficient cross-checking was done to establish a reasonable degree of reliability. The depths to water were measured when feasible; otherwise the most reliable past record or estimate was used. Data on acreage, by actual survey, and certain of the other data were obtained at the same time in connection with other investigations (11).

Figure 1, (page 24) a map of the main portions of the Valley, shows the locations of the wells sampled. A code number, adjacent to each well, indicates the type of water as regards electrical conductivity and sodium percentage. The map also shows ground water contours and irrigated areas. The former will be discussed later. The approximate limits of irrigable land were obtained by excluding all land on the periphery of the Valley coarser than Superstition sand (9). Non-irrigable areas, such as dune sand, within the Valley proper, were not excluded because of inadequate data. The limits shown are intended only as an indication of the gross irrigable area, and should not be interpreted too closely.

While comparisons on a valley-wide basis show wide ranges in water characteristics, composition within local ground water basins is usually rather uniform. Certain data, given in detail in Table 3, are summarized in Table 4. Variations in electrical conductivity indicate differences in saline content. The high conductivity water is normally found in shallow wells, or in wells drilled into the older alluvium at the edge of the Valley. From a relatively low sodium per cent water in the wells of the upper part of the Valley there is a gradual increase toward the lower end where sodium percentages of 90 are common. Variations in magnesium content are listed. Depths of well perforations and water temperatures are also given.

The character of the ground water is influenced largely by the nature of the watersheds. The main run-off, which has a low salt concentration, is from the high, precipitous, and granitic San Bernardino and San Jacinto Mountains. Ground waters fed from streams draining these high mountains traverse practically the entire length of the main axis of the long narrow valley. Palm Canyon, Deep Canyon, Martinez Canyon, and adjacent smaller canyons drain the lower Santa Rosa Mountains, and enter the Valley along the south side. The latter drainage basins are much drier than those of the high mountains, run-off is small in proportion, and flashy in nature. To the east and north are the desert sand hills and the dry Little San Bernardino Mountains, contributing only occasional flash floods.

The Valley fill to an undetermined depth is an alluvium from the surrounding mountains. The ground water moves in intermingling aquifers under pressure through this alluvium. There is undoubtedly considerable mixing, except when such mixing is hindered by faults or other barriers. In general, structural faults exist parallel to the main axis of the Valley on both the north and south sides, being especially noticeable on the north side (3). There is some evidence that other faulting exists. Fault zones, because of the nature and condition of the material, can affect the chemical nature of waters passing through them.

Not all the water passing through an aquifer flows parallel to the static water level; much of it may follow a parabolic pattern and reach considerable depths before appearing again near the surface (7). The environment and time involved for such passage are too uncertain to warrant a rigid interpretation of the hydrology and geology of the area from the chemical analyses of the water.

Returning to the specific character of Coachella Valley ground water, inspection of Table 4 discloses that the predominant ground water has a characteristic low salt content. Eighty-three of the 120 samples tested had a conductivity of 500 or less, and averaged 325. Of the above mentioned 83 wells, 36 had a sodium percentage of 50 or less, and averaged 35. They are, in general, located all along the Valley above the town of Coachella. Thirteen of the 83 wells had a sodium percentage between 51 and 70. Most of these are in the Coachella-Thermal area. From Coachella to the Salton Sea the sodium percentages were higher as a rule. Figure 2, (page 25) shows the progressive increase in sodium percentage for all low conductivity wells (500 or less) down the Valley from Palm Springs to the Salton Sea. As the conductivity of the water down the Valley is fairly constant, the increase in sodium percentage represents an increase in sodium ions accompanied by a decrease in calcium and magnesium ions.

Our information concerning the wells with conductivity above 500 is as follows:

a. Two of the three wells tested in the Garnet-Seven Palms Valley district, a somewhat isolated area, are of higher conductivity than waters in the Valley proper. The third has a moderately high sodium percentage.

b. Two wells and one spring near the mud hills north of Indio, an area where major faults run parallel to the main axis of the Valley, have water of relatively high salt content. This region has never been very productive of ground water.

c. In the central trough of the Valley south of Indio and Coachella are 5 relatively shallow wells which have more saline water than most of the wells of similar depth in the region. Three of these have top perforations from 85 to 128 feet below the surface, and two have gravel envelopes with top perforations 120 and 200 feet, respectively, below the surface. There are indications that deep seepage from the extensive overlying irrigated lands is responsible for the increase in salines.

d. Twelve wells with water of higher than average conductivity are in the Indian Wells district near the edge of Deep Canyon cone. Here, ground water contours indicate a slight influence on water levels of Deep Canyon water, and a subterranean barrier formed by the pro-

TABLE 2

CHEMICAL ANALYSES OF PRINCIPAL STREAMS DISCHARGING INTO COACHELLA VALLEY*

Stream	Sampling location †				Collected	Est. Flow ‡	Temp.	pH	Electrical Conductivity	Boron	Na §	Ca	Mg	Na	CO_3	HCO_3	SO_4	Cl	NO_3
	description	Twp.	Rge.	Sec.	date	c.f.s.	°F		micromhos/cm	p.p.m.	%	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e/l
Mission	Ctr. W½	2S	3E	2	12-27-31	..	..	..	793	0.03	25	3.94	3.16	2.41	..	4.31	4.95	0.25	Tr.
Mission	Ctr. W½	2S	3E	2	4-16-37	12.0	..	8.4	551	0.07	21	3.02	1.72	1.26	0.17	4.30	1.53	0.23	0.00
Whitewater	Nr. ctr. NW¼	2S	3E	35	4-13-37	45.0	67	8.3	347	0.08	17	1.77	0.88	0.54	0.13	2.99	0.12	0.13	0.00
Whitewater	Nr. ctr. NW¼	2S	3E	35	6-15-38	50.0	72	8.3	307	0.12	12	1.98	0.76	0.37	0.05	2.78	0.16	0.18	Tr.
Millard	SW¼ of NW¼	2S	2E	21	4-13-37	18.0	61	8.3	358	0.07	15	2.28	1.16	0.61	0.17	3.29	0.37	0.18	0.00
Potrero E. Br.	Nr. ctr. of SW¼	2S	2E	19	4-13-37	0.2	60	8.3	640	0.12	16	2.54	3.40	1.10	0.13	6.36	0.13	0.65	0.00
Potrero (Spr.)	Nr. ctr. E. side of SW¼	2S	1E	13	4-13-37	2.0	60	8.1	402	0.15	15	2.38	0.97	0.59	Tr.	3.41	0.47	0.15	0.00
Hathaway	SW cor. of NE¼ of NE¼	2S	1E	34	4-13-37	5.0	58	8.2	428	0.08	23	2.00	1.52	1.07	0.08	3.80	0.47	0.43	0.00
San Gorgonio	NE cor., NW¼ of SE¼	2S	1E	29	4-13-37	75.0	55	7.7	234	0.10	10	1.46	0.83	0.27	0.00	2.23	0.30	0.10	0.00
San Gorgonio	NE cor., NW¼ of SE¼	2S	1E	29	6-15-38	10.0	57	8.5	238	0.12	12	1.34	0.80	0.28	0.13	2.02	0.23	0.15	0.00
Snow	Nr. ctr. W. side, NW¼	3S	3E	33	4-13-37	60.0	54	8.0	81	0.05	26	0.66	0.11	0.27	0.00	0.89	Tr.	0.05	0.00
Snow	Nr. ctr. W. side, NW¼	3S	3E	33	6-15-38	25.0	60	8.0	77	0.08	25	0.59	Tr.	0.20	0.00	0.67	Tr.	0.13	0.00
Chino	SW¼ of SW¼	3S	4E	34	4-13-37	1.5	75	8.1	250	0.07	24	1.63	0.25	0.57	Tr.	2.53	0.09	0.13	0.00
Tahquitz	Nr. NE cor., SW¼	4S	4E	22	4-13-37	75.0	54	7.9	78	0.13	33	0.43	0.13	0.28	0.00	0.72	0.07	0.10	0.00
Tahquitz	Nr. NE cor., SW¼	4S	4E	22	6-15-38	20.0	64	7.8	65	0.10	34	0.45	0.11	0.29	0.00	0.62	Tr.	0.10	0.03
Andreas	Nr. SE cor. of SE¼	5S	4E	3	4-13-37	35.0	61	8.1	247	0.05	22	1.95	0.37	0.64	0.00	2.07	0.66	0.15	0.00
Andreas	Nr. SE cor. of SE¼	5S	4E	3	6-15-38	4.0	..	8.2	317	0.08	20	2.22	0.43	0.68	0.04	2.66	0.67	0.23	0.00
Murray	Nr. ctr. of NW¼	5S	4E	11	4-13-37	40.0	63	7.8	234	Tr.	23	1.26	0.42	0.49	0.00	1.48	0.44	0.23	0.00
Palm-W. br.	....	..	..	..	2-16-29	1.0	..	..	1240	0.20	14	7.52	3.95	1.94	...	3.40	7.63	2.40	..
Palm-W. br.	Nr. ctr. N side of SW¼	5S	4E	14	4-13-37	25.0	63	8.5	341	0.13	25	2.00	0.68	0.90	0.67	1.99	0.54	0.38	0.00
Palm-W. br.	Nr. ctr. N side of SW¼	5S	4E	14	6-15-38	2.0	72	8.1	438	0.18	24	2.40	0.92	1.04	Tr.	3.03	1.04	0.45	0.00
Palm	....	..	..	..	2-16-29	0.3	..	..	757	0.10	20	3.90	1.83	1.47	..	3.00	2.10	2.10	..
Palm	Nr. ctr. E. side, SW¼	5S	4E	14	2-16-29	1.0	..	..	1230	0.20	21	6.22	4.43	2.86	..	2.90	8.11	2.50	..
Palm	Nr. ctr. E. side NE¼ of SW¼	5S	4E	14	4-13-37	50.0	66	8.4	580	0.18	36	2.38	1.34	2.13	0.63	2.57	1.78	1.00	0.00
Palm	Nr. ctr. E. side NE¼ of SW¼	5S	4E	14	6-15-38	1.5	81	8.2	967	0.13	36	4.18	2.30	3.71	Tr	2.99	5.66	1.75	0.01
Deep	Nr. SW cor., SE¼ of NE¼	6S	6E	19	11-11-38	0.1	..	7.8	1300	0.11	24	6.97	4.14	3.47	...	3.29	8.57	2.90	0.04
Deep (Spr.)	100' below above record	6S	6E	19	11-11-38	0.1	..	7.6	1370	..	25	6.43	4.35	3.51	...	3.29	8.66	2.80	0.02
Martinez	Nr. grove cottonwoods	8S	7E	4	12-31-38	0.1	..	7.7	1680	Tr	19	9.78	6.40	3.73	...	4 63	14.15	1.65	0.04
To convert m.e./l (Milli-aquivalents per liter) to p.p.m. (parts par million), multiply by factor indicated.												20.0	12.2	23.0	30.0	61.0	48.0	35.5	62.0

* Samples collected prior to 1937 analyzed by, and used through the courtesy of Rubidoux Laboratory, Bureau of Plant Industry, U.S.D.A., Riverside, California.

† Referred to San Bernardino Base Meridian; Twp. township, Rge. range, Sec. section.

‡ Estimated flow in cubic feet per second.

§ Sodium as of total cations.

jection of Point Happy into the Valley.

Except for 2 wells in Section 20 (T.5S., R. 6E, in Figure 1) all of the higher conductivity Indian Wells district wells are relatively shallow, top perforations being from 75 to 129 feet below the surface. No other adjacent wells are perforated closer than 167 feet from the surface. The sandy soil is highly permeable, and heavy irrigations totalling 10 to 16 feet depth per year have been common (11). It is quite possible, then, that deep percolation from overlying irrigated lands may influence the salt content of the shallow wells. The two wells in Section 20 are reported to be perforated at depths of about 420 to 520 feet below the surface. The apparent depths of perforation would appear to throw some doubt on the theory that deep percolation from overlying irrigated lands is a causal factor in the higher salt content of these two wells, but do not preclude the possibility, especially since there might be leaks into the wells from shallow strata.

The higher conductivity wells in the Indian Wells district have remarkably high concentrations of nitrate. This will be discussed later.

e. Three wells with water of higher conductivity than average are east of Mecca on the lower end of the Mecca Canyon alluvial fan. Local well drillers report a stratum in this area "high in soda", which stratum is normally sealed off by them. The log for well 7-9 22b indicated the stratum at 350 to 360 feet depth. The owner states the water was of "excellent quality" until the casing was eaten away at that depth. Water of well 7-9-36 is similar, both being high in Ca, Na, and especially SO_4. Surface water levels show the influence of ground water moving down the Mecca Canyon alluvial fan.

f. Four wells of higher than average conduct tivity are in the western and southern parts of the Oasis area, and seven are in the south Salton area.

Surface water levels in these areas are influenced by the flow from Martinez Canyon. The higher salt content, and change in proportions of some ions, are indicative that the waters from these wells may be partially from a separate source (notably Martinez Canyon) rather from the main valley.

For the dominant waters of the Valley, the trend in sodium percentage has been stressed. Of equal importance is the negative correlation of magnesium content with distance down the Valley for wells with conductivity under 1000. This is illustrated in Figure 2, (page 25), along with the per cent sodium trend. The deficiency in magnesium in the lower end of the Valley will be discussed later.

The temperatures of the waters in the Oasis and south Salton areas are significantly higher than for waters of comparable composition in t the Thermal-Mecca areas. This abrupt change in water temperature indicates the possible presence of a subterranean barrier.

High nitrate waters

The high nitrate content of some well waters in the Indian Wells area is an interesting subject on which some time was spent in an attempt to determine the nitrogen source. The first approach was to determine the character of water replenishing the ground water supply. The nitrogen content of the Deep Canyon surface supply, as well as of the supplies originating in the main streams, was low. Stream waters could, therefore, be eliminated as the source of the nitrogen supply.

Growers of dates normally use relatively large amounts of nitrogenous fertilizer. As the soils of this section are relatively coarse textured and the amounts of irrigation water applied are large, there is undoubtedly some nitrate leached to the ground water. It is very doubtful, however, that the quantity of nitrogen that has been added by this means would account for the large amounts found in the pumped water supply.

In parts of this area, forests of large mesquite trees are found. Under natural conditions there is a gradual accumulation of litter upon the soil surface, often a half foot in thickness. Samples of this litter were found to contain 2.3% nitrogen. Incubation at room temperature of soil samples containing 5% by weight of litter showed a rapid breakdown of organic matter.

Soil samples were taken to a depth of nine feet in a mesquite covered area and from a nearby sagebrush tract. One to five aqueous extracts of these soil samples showed the following amounts of nitrate present, expressed as milli-equivalents of nitrate (NO_3) per kilogram of soil.

Depth, feet	Mesquite	Sagebrush
0--1	5.1	7.9
1--2	24.9 *	10.7
2--3	9.3	9.7
3--4	16.4	5.5
4--5	15.7	4.0
5--6	7.4	4.0
6--7	7.1	3.2
7--8	9.6	0.9
8--9	4.5	---

*This represents about 630 pounds of nitrogen per acre foot of soil, an extremely high value.

Analysis of a 1:1 aqueous extract of a soil sample taken from beneath the mantle of litter in a mesquite forest showed the following composition, expressed as milli-equivalents per liter: calcium, 18.0; magnesium, 5.7; potassium, 6.1; sodium, trace; bicarbonate, 1.6; sulphate, 6.3; chloride, 5.1; and nitrate, 17.4. Normally, water extracts of California soils are low in potassium and nitrogen. In this soil sample, however, these constituents are present in especially large amounts.

When mesquite forests are subjugated and the land placed under irrigation an entirely different environment is established than prevailed under natural conditions. Organic matter is quickly decomposed and soluble constituents are leached to the ground water by heavy applications of irrigation water. Pumping produces a drawdown in the water table causing a gradient toward the well. Under this condition, shallow wells in particular could become contaminated by soluble material from the overlying irrigated lands. This hypothesis might explain the source of a large part of the high nitrate content of some of the well waters. Considerable fluctuation and a gradual reduction in the nitrogen content can be seen from the analyses. Indications are that decomposing organic matter is the localized source of the nitrogen.

TABLE 3

CHEMICAL ANALYSES AND HYDROLOGICAL DATA FOR REPRESENTATIVE WELLS IN COACHELLA VALLEY, CALIFORNIA

Well	Location in Section	Elev.	Well depth data: Total	Well depth data: Perforations	Depth to Water: Static	Depth to Water: Pump	Dis-charge	Area irri-gated	Col-lected	Temp	pH	Electrical Conductivity	Boron	Na	Ca	Mg	Na	CO_3	HCO_3	SO_4	Cl	NO_3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
no.		feet	feet	feet	feet	feet	c.f.s.	acres	date	°F		micromhos/cm	p.p.m.	%	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l
3-4-15	SE¼ of SE¼	710±	203	195-203	180	180	...	Dom.	7-13-38	..	8.4	358	0.03	69	0.93	0.19	2.46	Tr.	2.34	0.63	0.46	0.03
3-5-17a	SW¼ of NE¼	800±	400	342-400	23	50	1.5	13	7-13-38	85	8.5	1290	0.45	60	3.20	1.11	8.20	Tr.	1.73	8.56	2.00	0.08
3-5-17b	NW¼ of SE¼	800±	801	317-350	40	70	1.3	Dom.	7-13-38	85	8.1	1310	0.40	67	3.20	1.02	8.41	Tr.	1.90	8.70	2.09	0.10
4-4-14	SW¼ of NW¼	450±	0	Hot Spring	...	...	0.1	...	9- 6-38	106	9.2	356	0.23	94	0.18	Tr.	3.04	1.68	0.15	0.42	1.00	0.00
4-4-23	SW cor., NW¼ of SE¼	430±	550	...	150	152	0.1	Dom.	7-13-38	67	7.9	308	Tr.	24	1.91	0.45	0.76	0.00	2.13	0.32	0.51	0.12
4-4-25	Nr. NW cor.	430±	500	320-500	128	...	0.3	Dom.	1-28-39	..	8.0	434	0.05	25	2.83	0.83	1.20	...	3.01	1.28	0.32	0.14
4-5-13	Ctr. S. side, NE¼	250	300	202-212. 277-297	73	...	...	Dom.	9-12-38	..	8.5	344	0.15	21	2.06	0.73	0.75	0.42	2.36	0.45	0.29	0.00
4-5-33	NW cor. NE¼	295	363	295-354	80	100	0.5	Dom.	7-13-38	68	8.2	421	0.07	21	2.42	0.60	0.78	0.00	2.38	0.72	0.63	0.04
4-6-12	SW¼	500±	0	Spring	...	...	0.1	40	12- 1-37	Cold	...	2050	1.39	80	3.07	1.01	16.52	0.30	2.12	13.56	4.31	Tr.
4-6-27	Ctr. N. side, SW¼ of SW¼	164	794	506-563	60	125	4.0	600P	12-12-36	72	7.4	...	...	45	1.20	1.56	2.22	...	2.85	0.33	1.78	...
4-6-28	SE cor. NE¼	167	1056	192-1056	52	76	8.0	600P	7-13-38	72	7.6	332	0.02	29	1.90	0.44	0.96	0.00	2.44	0.41	0.31	0.04
5-5-13	NE cor.	218	216	...	90	100	0.5	Dom.	12-12-38	..	8.0	436	0.12	27	2.52	0.65	1.30	Tr.	2.47	1.14	0.62	0.19
5-6-7	NW cor.	223	267	90-155, 226-236	80	85	3.0	75	8-23-38	69	8.0	289	0.07	31	1.66	0.36	0.89	Tr.	2.15	0.35	0.38	0.00
5-6-20a	NE cor. SE¼ of NE¼	199	522	435-522	...	97	3.0	170P	1-10-39	72	7.8	1270	0.05	38	7.95	2.02	4.44	...	3.00	5.06	3.70	2.74
5-6-20b	NE cor. SE¼ of NW¼	198	497	420-497	...	98	2.4	170P	1-14-39	71	7.6	1150	0.03	18	7.60	1.60	2.08	...	3.37	3.23	4.36	0.14
5-6-21a	SW cor. E½ of NE¼	201	320	Approx. 220-320	...	104	1.3	70P	12-12-38	71	7.9	399	0.20	23	2.17	0.57	1.33	0.00	2.34	1.05	0.64	0.08
5-6-21b	NE cor. W½ of SW¼ of NE¼	192	300	129-139,194-213,235-283	...	100	1.4	59P	12-12-38	70	7.9	648	0.02	25	3.83	0.88	1.60	0.00	2.40	1.86	1.07	1.00
5-6-21c	SW cor. E½ of SW¼ of NE¼	205	251	167-192,197-237	98	112	0.9	59P	12-12-38	71	8.0	399	0.25	30	2.31	0.66	1.30	Tr.	2.38	1.20	0.59	0.09
5-6-22a	Nr. SW cor. E½ of NE¼ of SW¼	180	203	100-128,162-170	80	96	1.2	10	10-5 -38	77	8.2	1370	0.25	30	8.30	0.75	3.96	Tr.	2.46	4.47	2.73	3.37
5-6-22a	....	...	...	....	..	...	...	..	12-19-38	..	8.2	1480	...	..	3.33	...	...	...	2.63	...	2.17	3.14
5-6-22a	....	...	...	....	..	...	...	...	12-15-40	..	...	643	0.11	42	3.00	0.73	2.65	0.00	2.50	2.06	1.06	0.57
5-6-22b	Nr. SE cor. SW¼ of NE¼	156	140	....	61	83	0.5	39P	7-13-38	75	8.1	1090	0.35	44	4.86	1.08	4.76	0.00	3.14	4.51	2.06	1.20
5-6-22b	....	...	...	....	...	...	...	...	11-17-38	..	8.2	1040	....	45	4.73	1.07	4.66	...	3.12	3.97	1.85	1.24
5-6-22c	Ctr. W side, SW¼ of NE¼	161	500	288-298, 346-404,420-474	63	74	1.7	39P	7-13-38	..	8.2	351	0.03	33	1.81	0.47	1.20	Tr.	2.25	0.12	0.60	0.60
5-6-22c	....	...	...	....	...	...	...	...	11-17-38	..	8.2	341	....	34	1.82	0.44	1.14	...	2.21	0.17	1.00	0.08
5-6-22c	....	...	...	....	...	...	...	...	1-14-39	70	8.2	347	....	..	...	...	...	...	2.30	...	0.54	0.10
5-6-22d	SE cor. W½ of NW¼ of SW¼	196	342	222-260, 287-340	...	101	1.1	40	7-13-38	77	8.2	445	0.05	34	2.26	0.47	1.57	Tr.	2.19	1.33	0.74	0.03
5-6-22e	SW cor. N½ of SE¼ of SW¼	192	250	....	...	103	0.7	5	11-11-38	..	8.2	770	....	39	3.59	1.01	2.93	...	2.19	3.88	1.15	0.50
5-6-22f	Ctr. W side, S½ of SE¼	183	302	95-170, 215-220, 260-298	...	100	1.3	75P	11-17-38	..	8.0	530	0.07	29	2.74	1.06	1.59	...	2.61	2.19	0.75	0.02
5-6-22g	SW cor. NW¼	191	209	75-100, 106-130, 136-142	88	110	1.1	25	11-17-38	73	8.1	507	0.10	34	2.30	1.05	1.73	...	2.61	1.05	1.00	0.30
5-6-22h	NW cor. SW¼ of SW¼ of NW¼	186	200	84-126	...	102	0.9	20	11-17-38	72	8.1	770	....	28	4.44	1.08	2.12	...	3.37	2.03	1.55	0.89
5-6-22i	SW cor. SE¼ of NW¼	179	247	75-101, 110-125, 222-240	81	104	1.0	12	11-17-38	74	8.2	888	....	29	4.93	1.34	2.53	...	2.70	2.41	1.80	1.93
5-6-22j	NW cor. S½ of SW¼ of SW¼	207	208	Cut 35' near bottom	108	121	0.7	27	12-12-38	79	8.0	491	0.10	39	2.54	0.51	1.95	Tr.	2.63	1.66	0.70	0.05
5-6-26	300'± S of NW cor.	158	545	100-545	...	...	2.5	100P	11-9-38	..	...	2170	0.23	36	11.56	2.98	8.22	0.00	2.07	12.15	7.96	0.86
5-6-27	Ctr. NE¼	...	424	270-424	95	122	3.1	256P	5-8-40	..	...	558	0.11	34	2.73	1.10	1.98	0.30	2.39	2.17	0.67	0.04
5-7-3	NW cor. SW¼	38	750	200-750 Gravel env.	31	49	2.6	70	8-23-38	77	7.9	818	0.07	63	2.24	0.78	5.22	0.00	1.69	5.01	1.56	0.00
5-7-6	Nr. NE cor. NW¼ of NE¼	92	314	168-180, 280-303	45	84	1.8	40	9-12-38	72	8.2	316	0.03	28	1.73	0.63	0.92	Tr.	2.44	0.54	0.25	0.02
5-7-12	NW cor.	50	451	214-262, 295-434	...	...	0.6	1	9-13-38	78	8.6	1080	0.10	85	0.97	0.43	8.28	0.50	1.78	5.72	1.75	0.03
5-7-21a	SE cor. NW¼ of SE¼	29	730	....	50	83	1.5	100P	4-19-38	..	7.9	302	0.04	40	1.40	0.52	1.27	Tr.	2.45	0.32	0.25	0.05
5-7-21b	20'± S of 5-7-21a	29	500	....	50	82	2.0	100P	12-27-37	..	7.8	296	0.04	31	1.69	0.45	0.94	Tr.	2.27	0.49	0.35	0.01
5-7-22	NW¼ of NW¼	14	556	516-554	42	62	0.5	Dom.	10-13-34	..	..	321	0.04	28	1.71	0.68	0.93	...	2.66	0.35	0.34	0.02
5-7-22	....	...	...	....	...	...	...	...	3-20-38	..	7.7	319	0.03	31	1.80	0.78	1.17	0.00	2.83	0.44	0.35	0.04
5-7-24	Nr. NW cor. NE¼ of SW¼	-17	1224	1062-1104, 1140-1206	22	...	1.2	Ind.	7-29-38	70	8.4	277	Tr.	71	0.70	0.04	1.78	0.34	1.37	0.55	0.43	0.03
5-7-25	SW cor. NW¼	-18	1390	611-13,645-47,1010-1150	29	72	2.2	120P	8-23-38	73	8.1	293	0.03	46	1.07	0.49	1.34	Tr.	2.13	0.40	0.60	0.00
5-7-26	NW cor. SE¼	-10	400	108-326	53	102	2.9	120P	9-16-37	73	8.1	847	0.09	29	5.05	1.01	2.53	0.30	2.17	3.32	2.45	0.04
5-7-28a	1300' NW of SE cor. of NE¼	32	660	524-534,549-552,582-636	58	75	1.5	41P	9-13-38	69	8.2	310	0.13	32	1.56	0.65	1.05	Tr.	2.63	0.31	0.29	0.04
5-7-28b	700'± NE of ctr. sec.	38	648	510-540, 567-638	64	72	0.9	41P	9-26-38	69	7.9	295	0.03	32	1.60	0.49	0.97	0.00	2.42	0.40	0.21	Tr.
5-7-28c	200'S, 1620'E of ctr. sec.	33	243	85-103, 151-162, 198-228	77	99	0.5	12	8-4-38	74	8.0	408	0.05	34	2.28	0.58	1.46	Tr.	3.12	0.53	0.50	0.07
5-7-30	NE cor NW¼	72	222	77-126, 140-192	66	88	1.0	28P	7-19-38	75	8.0	493	Tr.	39	2.31	0.57	1.89	0.00	2.47	1.38	1.00	0.13
5-7-34a	NW¼ of SE¼ of NE¼	9	178	110-178	70	87	0.8	50P	7-19-38	73	7.7	921	0.02	33	5.27	1.08	3.15	0.00	3.62	3.67	1.59	0.75
5-7-34b	NW cor. SE¼	12	300	90-154, 200-232, 251-288	...	...	1.2	50P	7-19-38	73	8.1	354	0.02	39	1.87	0.35	1.39	0.00	2.34	0.39	0.51	0.11
5-7-35	Nr. SE cor. SW¼ of NW¼	-3	300	150-300	90	110	...	70	12-21-38	72	8.2	312	....	39	1.70	0.43	1.34	...	2.32	0.65	0.30	0.04
5-8-31a	Ctr. W side, NE¼ of NE¼	-50	328	93-96, 185-201, 272-316	27	...	1.0	20	9-13-38	73	8.2	304	0.02	43	1.39	0.38	1.33	Tr.	2.42	0.41	0.31	0.00
5-8-31b	Adjacent to 5-8-31a	-50	1026	1013-1026	...	...	0.2	Dom.	9-13-38	..	8.2	280	Tr.	59	0.75	0.39	1.64	Tr.	1.88	0.46	0.39	0.02
6-6-1	SW cor. SE¼ of SW¼ of NE¼	46	296	205-296	78	82	0.8	11	7-19-38	82	8.3	307	0.05	70	0.72	0.11	1.95	0.21	1.24	0.52	1.10	0.02
6-7-1a	Ctr. N side, NW¼ of NE¼	-40	325	200-325	...	78	0.8	41P	7-18-38	72	8.4	322	Tr.	31	1.93	0.32	1.03	Tr.	2.21	0.58	0.46	0.06
6-7-1b	310' W, 720'S of ctr. N side	-42	300	120-300	...	54	0.9	41P	1-13-39	72	7.8	287	Tr.	37	1.59	0.27	1.11	...	2.22	0.38	0.34	0.12
6-7-4a	900'W of NE cor. of NW¼	31	189	91-92, 94-96, 97-111	...	...	1.0	49P	7-18-38	70	7.6	262	0.03	36	1.46	0.25	0.95	0.00	1.88	0.44	0.32	0.05
6-7-4b	Nr. ctr. NW¼ of NE¼	24	134				1.0	49P	7-15-38	73	8.0	290	Tr.	42	1.58	0.19	1.26	Tr.	1.92	0.56	0.39	0.07
6-7-13a	Nr. NE cor. SE¼ of NW¼	-63	205	66-78,112-115,124-144	38	54	0.8	10	7-18-38	72	8.5	263	0.03	42	1.28	0.20	1.06	0.08	1.82	0.35	0.29	0.05
6-7-13b	100'SE from NW cor. NE¼	...	130	....	42	...	0.8	..	8-21-41	..	...	1540	0.10	46	7.12	1.18	7.00	Tr.	2.05	7.60	5.75	0.06
6-7-17	NW cor. SE¼ of SE¼	-5	350	325-350	79	94	0.9	130P	9-6 -38	75	7.4	288	Tr.	49	0.99	0.52	1.46	0.00	1.94	0.21	0.63	0.00
6-7-23a	NE cor. SW¼ of SW¼	-64	632	120-632 Gravel env.	44	58	2.3	240P	7-18-38	..	8.1	1270	0.15	50	5.15	0.82	6.01	0.00	2.07	5.13	4.91	0.20
6-7-23b	Nr. NW cor. NE¼ of NW¼	...	1263	836-1263	24	40	1.0	40	11-27-40	..	...	256	0.04	75	0.58	0.13	2.10	0.10	1.69	0.37	0.30	0.04
6-7-23c	Nr. NW cor. NE¼	...	600	0-600	40	50	1.2	27	11-27-40	..	...	262	0.07	53	1.07	0.16	1.38	Tr.	1.99	0.40	0.25	0.03
6-7-24	Ctr. W side, NW¼ of NE¼	-77	1414	966-1170, 1260-1402	0	...	1.2	34	1- ?-19	..	...	...	...	61	0.75	0.25	1.57	0.00	1.75	0.40	0.34	...
6-7-24	....	...	...	....	..	...	...	..	1- 8-30	72	...	242	0.02	77	0.54	0.00	1.85	...	1.65	0.34	0.40	...
6-7-24	....	...	...	....	..	...	...	..	9- 6-38	76	8.0	271	0.20	74	0.64	Tr.	1.80	Tr.	1.69	0.39	0.40	0.00
6-7-25	900'E of NW cor. SW¼	-85	218	62-68, 112-124	31	60	0.2	8	7-19-38	73	8.1	361	Tr.	59	1.27	0.20	2.09	Tr.	1.96	0.67	0.97	0.01
6-8-5	NW cor. SE¼ of SE¼	-81	640	206-306, 540-640	30	40	0.6	Dom.	7-13-38	..	8.3	272	0.07	58	1.09	0.13	1.66	Tr.	1.75	0.48	0.56	0.02
6-8-6a	200'E of NW cor.	-44	113	100-113	..	..	0.6	20	9-27-38	74	7.8	435	0.07	30	2.60	0.50	1.31	0.00	2.49	1.01	0.80	0.02
6-8-6b	NW cor. SE¼ of SW¼	-58	540	490-540	34	50	1.0	16	9-27-38	72	7.9	287	0.04	41	1.38	0.25	1.32	0.00	2.15	0.50	0.25	0.04
6-8-10	NW cor. SW¼ of SE¼	-105	525	110-525 Gravel env.	12	29	1.1	22	10-19-34	..	...	...	....	45	0.65	1.47	1.74	0.00	1.80	1.75	0.39	...
6-8-11a	NW cor. SW¼ of SW¼	-109	640	610-640	8	45	0.5	15	9-13-38	..	7.4	302	0.03	62	0.88	0.24	1.83	0.00	1.83	0.81	0.34	Tr.
6-8-11b	NW cor. E½ of SW¼ of SW¼	-107	400	90-400 Gravel env.	..	...	...	19	9-13-38	75	7.9	466	0.10	85	0.65	Tr.	3.62	Tr.	2.17	1.48	0.69	Tr.
6-8-17	Nr. ctr. NE¼	...	140	....	50	...	0.1	20	8-23-40	..	...	274	0.05	50	1.16	0.17	1.31	Tr.	1.91	0.43	0.25	0.03
6-8-20	In NE¼	...	1020	217-	22	72	1.5	..	7-15-43	..	7.9	251	0.01	63	0.84	0.06	1.52	0.00	1.69	0.46	0.25	0.03
6-8-21	NW cor.	-113	517	....	..	...	0.2	20	9-27-38	73	8.2	263	0.01	53	1.13	0.15	1.44	Tr.	1.90	0.41	0.35	0.01
6-8-24	SE cor.SW¼ of SE¼	-103	1245	760-1245	56	156	0.6	0	6-17-32	80	...	248	0.06	86	0.30	0.07	2.19	...	1.55	0.70	0.30	0.01
6-8-25	SW cor. N½ of NW¼	-132	724	72-603	33	71	3.1	256P	6-15-32	78	...	429	0.06	64	0.94	0.39	2.38	...	1.25	1.56	0.90	Tr.
6-8-25	....	...	...	....	...	...	...	...	7-19-38	76	8.6	504	0.07	72	1.29	0.12	3.56	0.46	1.20	1.94	1.38	0.00
6-8-28	In SE¼	...	720	220-	...	...	1.5	...	7-15-43	..	8.9	249	Tr.	62	0.87	0.06	1.49	0.20	1.44	0.49	0.26	0.03
6-8-30	600'W of NE cor. NW¼	-102	108	85-108	...	...	0.5	25P	7-19-38	72	7.7	2490	0.08	40	12.50	2.52	10.19	0.00	3.16	10.70	11.45	0.30
6-8-32b	NW cor. SE¼ of SE¼	-136	1025	1000-1025	Flowing		1.0	52P	9-27-38	81	8.8	224	0.06	91	0.20	Tr.	1.94	0.88	0.60	0.36	0.28	0.03
6-8-36	NW cor. SW¼	-155	1880	1540-1880	Flowing		0.2	0	12-9 -36	..	7.7	246	0.08	44	0.46	1.03	1.16	0.00	1.64	0.54	0.40	0.02
7-8-2a	In E½ of NE¼ of NE¼	-162	500	....	...	...	...	0	12- -33	..	...	...	....	74	0.55	0.16	1.96	0.10	1.46	0.77	0.37	...
7-8-2b	400' W of NE cor.	-161	600	500-600	...	23	0.5	12	9-13-38	75	8.6	239	Tr.	79	0.48	Tr.	1.77	0.62	0.79	0.51	0.36	0.00
7-8-2c	Nr. NW cor.	-160	...	....	Flowing		0.5	0	11-25-38	72	8.3	246	0.22	66	0.75	0.10	1.62	0.04	1.51	0.66	0.31	0.06
7-8-4a	200'E of NW cor. NE¼	-152	452	440-452	Flowing		0.1	Past.	9-27-38	73	8.1	242	0.02	69	0.63	0.11	1.61	Tr.	1.58	0.47	0.28	0.04
7-8-4b	NW cor. SE¼	-155	912	550-890, 896-912	Flowing		0.1	Past.	9-27-38	77	8.5	254	0.05	84	0.35	0.03	2.05	0.25	1.29	0.52	0.39	0.03
7-8-7a	200' N of SW cor. SE¼ of SE¼	-90	618	300-618	64	...	1.3	39	12-29-37	..	8.0	230	0.03	86	0.18	0.10	2.01	0.20	1.11	0.45	0.30	0.02
7-8-7b	Nr. SE cor.	-90	225	185-225	...	...	0.1	Dom.	4-30-32	..	...	...	....	83	0.36	0.05	1.98	...	1.32	0.43	0.68	...
7-8-7c	185' NW of 7-8-7b	-90	312	110-118,248-253,274-288	...	...	...	Dom.	9-13-38	78	8.2	233	0.02	78	0.46	Tr.	1.67	Tr.	0.86	0.52	0.54	0.00
7-8-12	850' W of ctr. sec.	-183	568	476-486, 555-568	Flowing		0.2	5	9-12-38	73	8.1	245	0.03	87	0.30	Tr.	1.92	Tr.	1.39	0.53	0.34	0.00
7-8-16	Nr. NW cor. SE¼	-126	600	490-525	26	91	1.1	20	7-29-38	75	8.5	240	0.02	80	0.33	0.09	1.71	0.42	0.95	0.50	0.43	0.03
7-8-34a	900'S, 300'E of NW cor. SE¼	-85	895	300-895 Gravel env.	73	84	1.7	74	7-18-38	94	9.4	354	0.07	87	0.45	Tr.	2.92	0.72	0.60	1.07	0.93	Tr.
7-8-34b	1280'W, 520'S of NE cor.	-102	1013	308-98,450-58,820-38,910-101	47	85	0.8	48	7-18-38	95	9.6	314	0.10	93	0.21	Tr.	2.67	1.01	0.51	0.70	0.50	0.00
7-8-34c	Nr. SE, cor. NE¼ of NE¼	-122	250	82-87, 173-215,	...	...	...	Dom.	7-18-38	86	9.2	256	0.05	77	0.62	Tr.	2.06	0.76	0.86	0.59	0.40	0.01
7-8-35a	Ctr. S½, SE¼ of NW¼	-158	900	310-900	2	20	0.6	10	2-18-37	96	8.3	301	0.10	89	0.20	0.16	2.81	0.45	1.36	0.94	0.65	0.02
7-8-35b	NW cor. S½ of SE¼ of NW¼	-147	1180	175-1180	10	28	0.6	40	4-20-37	96	8.6	340	0.07	88	0.32	0.09	2.96	1.02	0.62	0.96	0.65	0.01
7-8-35f	Ctr. S½. SW¼ of NW¼	...	1015	600-1015	20	35	0.5	40	9-26-43	..	8.9	299	0.15	96	0.10	0.01	2.73	0.89	0.74	0.75	0.42	Tr.
7-9-8	Nr. SW cor. (W of track)	-192	1511	1410-1485	Flowing		...	Ind.	7-29-38	..	8.6	322	0.07	87	0.35	0.06	2.67	0.55	0.46	1.76	0.49	0.03
7-9-16	100'S of NW cor. NW¼ of SW¼	...	916	....	0	57	0.3	...	11- 7-40	..	...	315	0.08	97	0.10	Tr.	3.03	0.31	1.64	0.78	0.20	Tr.
7-9-17	700'S of NW cor. NE¼	-189	880	800-880	Flowing		0.6	25	9-12-38	81	9.0	253	0.05	89	0.25	Tr.	2.00	1.35	0.15	0.58	0.36	0.00
7-9-21	N of hwy. Nr. SE cor. NE¼	-194	603	300-603	...	...	...	15	9-12-38	78	8.3	481	0.15	67	1.41	Tr.	2.92	0.25	1.46	2.39	0.40	0.00
7-9-22a	Nr. NE cor. SW¼ of SW¼	-199	600	400-412, 560-570, 590-600	0	32	0.2	7	9-27-38	79	9.1	254	0.03	89	0.24	0.02	2.17	1.14	0.17	0.77	0.30	0.00
7-9-22b	10' N of 7-9-22a	-199	412	350±-360±, 400-412	Flowing		...	0	9-27-38	..	7.9	1710	0.10	61	5.34	1.37	10.56	0.00	1.56	15.22	0.63	0.00
7-9-25	Ctr. N side, NW¼ of NW¼ of SW¼	...	600	480-600	8	25	0.8	100	4- 3-39	..	...	665	0.14	94	0.33	0.06	6.00	0.61	1.72	1.53	2.06	0.01
7-9-27	NE cor. SW¼	-219	651	600-651	Flowe	30	0.2	Pond	9-12-38	81	8.9	387	Tr.	94	0.21	Tr.	3.36	0.84	1.48	1.00	0.33	0.01
7-9-29	300' SE of NW cor.	-217	610	290-610 Gravel env.	Flowing		1.2	Pond	9-12-38	76	9.0	254	0.05	90	0.25	Tr.	2.17	1.47	0.05	0.61	0.34	0.00
7-9-36	300' SW of NE cor.	-228	575	515-575	Flowing		0.2	Dom.	2-24-38	85	8.4	1200	0.14	61	4.43	0.29	7.46	0.41	1.43	9.46	0.67	0.01
8-8-1a	SW cor. SE¼ of SW¼	-185	325	....	Flow	12	1.0	40	12-28-37	89	8.5	370	0.14	90	0.19	0.17	3.08	0.40	1.01	1.52	0.30	Tr.
8-8-1b	Nr. Ctr. N side. SE¼ of NW¼	-195	789	350-789	Flowing		0.5	300P	12-10-38	80	8.6	306	0.15	93	0.19	0.13	2.78	0.14	1.54	0.92	0.32	0.02
8-8-4a	900'S, 1000'W of NE cor.	-14	430	200-430	138	143	2.9	125	2-18-37	100	8.0	726	0.05	70	1.47	0.65	5.00	0.00	1.58	2.12	3.54	0.05
8-8-11a	Ctr. NE¼ of NW¼	-135	860	740-777,797-820,860	...	47	0.8	46	7-14-38	103	9.5	362	0.23	95	0.18	Tr.	3.21	1.31	0.02	1.27	0.64	0.01
8-8-11b	Ctr.S side, N½ of SW¼ of NE¼	-148	561	549-561	15	30	0.4	20	11- 9-35	94	...	328	0.11	96	0.12	Tr.	2.88	0.99	0.59	1.02	0.43	0.00
8-8-13a	Ctr. N½ of NW¼	-159	960	742-952	15	49	2.4	55P	2-23-37	100	8.6	398	0.22	93	0.15	0.14	3.68	1.02	0.96	0.90	0.90	Tr.
8-8-13b	Nr. ctr. SE¼ of NW¼	-156	824	700-824	10	30	2.4	73	6-15-38	106	8.5	426	0.27	95	0.15	0.04	3.90	0.72	1.26	1.01	1.13	0.00
8-8-13c	600' SE of ctr. sec.	-150	818	706-800	25	41	0.6	32	6-15-38	104	8.5	699	0.30	90	0.48	0.16	5.48	0.34	1.09	1.49	3.38	Tr.
8-8-14	300'N of SW cor. NE¼ of NE¼	-134	340	Prob. 280-340	18	36	0.8	40	2-18-37	92	8.2	310	0.08	90	0.16	0.17	2.94	0.23	1.52	1.07	0.70	0.01
8-8-24a	300'S of NW cor NE¼ of NE¼	-155	910	800-900	15	30	2.5	59P	7-18-38	109	9.0	604	0.28	91	0.38	Tr.	5.09	0.88	0.60	1.33	2.76	0.03
8-8-24d	Nr. NW cor. SE¼ of NE¼	...	...	....	Flow	20	0.3	20	11- 7-40	95	...	1390	0.41	67	4.47	Tr.	9.07	0.00	0.51	10.64	2.46	Tr.
8-9-29	Ctr. W side, SW¼ of NW¼	-150	605	....	...	39	1.1	28	10-21-38	106	8.7	675	0.48	93	0.45	Tr.	5.38	0.54	0.47	1.48	3.39	0.03
8-9-33a	300'S of NW cor.	-174	690	580-690	6	51	1.4	40	5-25 37	[illegible]	7.0	1740	0.71	85	2.14	0.08	12.67	[illegible]	1.02	1.80	12.04	0.14
8-9-33b	Nr. ctr. NE¼ of NW¼	-191	350	200-350	0	25	0.5	20	5-25-37	95	8.2	2170	0.79	86	2.33	0.57	17.43	0.45	1.47	6.30	11.92	0.11
8-9-33c	NW cor. SW¼ of NW¼ of NE¼	-202	197	167-197	-12	...	0.5	35P	[illegible]	88	8.6	[illegible]	0.05	93	0.41	Tr.	5.35	0.58	1.51	2.75	1.11	0.00
8-9-33d	Ctr. W side, SE¼ of NW¼	-176	316	144-150, 159-169	0	...	...	41P	9-13-38	99	7.9	3720	0.27	82	3.82	2.20	27.01	Tr.	1.16	[illegible]	22.87	0.05
8-9-33e	Ctr. W side, S½ of NE¼	-192	865	703-8[illegible]6	Flowing		...	41P	9-13-38	119	7.8	6060	0.35	79	10.92	1.87	42.65	0.00	0.76	6.39	48.00	0.19
[illegible]	[illegible]		[illegible]	[illegible]	0	30	[illegible]	...	11- 7-40	90		....			...	...	...	...	...	...	...	
8-11-10	....	...	97	....	Flowing		0.3	Dom.	5- 3-38	82	7.9	3400	2.90	78	3.69	3.40	24.60	0.20	3.17	3.96	24.30	0.01
To convert E. P. M. to parts per million (p.p.m.) multiply by factor indicated															20.0	12.2	23.0	30.0	61.0	48.0	35.5	62.0

DESCRIPTION OF CERTAIN DATA BY COLUMNS

Column 1: First number is township south of San Bernardino Base; second number is range east of San Bernardino Meridian; third number is section. Letters follow section number where necessary to distinguish two or more wells in one section.

3 Elevation of ground surface at well in feet approximated from U. S. Bureau of Reclamation maps (contour interval = 2 ft.) for area within Improvement Dist. No. 1. For other wells, elevations estimated from U.S.G.S. and County maps (contour interval = 100 ft.). Minus sign indicates elevation below sea level.

6 Minus sign indicates water under pressure.

9 "Ind." refers to railroad industrial use, "Dom." to domestic use, "P" indicates other wells also used to irrigate acreage shown.

12 Determined with glass electrode pH meter (except early records).

14 "Tr." is less than 0.01 p.p.m.

15 Per cent sodium as of total cations.

16-23 m.e./l = milli-equivalents per liter.

16-22 "Tr." is less than 0.04 m.e./l.

23 "Tr." is less than 0.01 m.e./l.

Note: 34 analyses courtesy Rubidoux Laboratory, Bureau of Plant Industry, U.S.D.A., Riverside, California. Also 2 analyses privately made.

TABLE 4

SUMMARY OF OUTSTANDING CHEMICAL CHARACTERISTICS OF COACHELLA VALLEY GROUND WATERS
GROUPED BY TYPE OF WATER, WITH DEPTHS OF PERFORATIONS AND TEMPERATURE.
(Average values and standard errors)

Type of water	Type Code	Wells	Electrical Conductivity at 25°C	Sodium	Magnesium (Mg)	Perforations (from surface) Top	Bottom	Temperature
		no.	micromhos/cm	percent	e.p.m.	feet	feet	°F
Conductivity 0 to 500								
% sodium 0 to 50	11	36	350 ± 10	35 ± 1	0.55 ± 0.05	284 ± 31	460 ± 60	72 ± 1
% sodium 51 to 70	12	13	300 ± 20	62 ± 2	0.16 ± 0.02	315 ± 86	580 ± 78	75 ± 2
% sodium over 70	13	34	300 ± 10	86 ± 1	0.06 ± 0.01	517 ± 59	786 ± 58	85 ± 2
Conductivity 501 to 1000								
% sodium 0 to 50	21	9	720 ± 50	31 ± 1	1.07 ± 0.04	118 ± 23	279 ± 31	73 ± 1
% sodium 51 to 70	22	2	770 ± 40	66 ± 4	0.72 ± 0.06	200 ± 0	590 ± 160	88 ± 12
% sodium over 70	23	5	660 ± 20	92 ± 1	0.06 ± 0.03	538 ± 141	626 ± 123	102 ± 4
Conductivity over 1000								
% sodium 0 to 50	31	8	1540 ± 180	38 ± 1	1.62 ± 0.03	210 ± 69	347 ± 76	73 ± 1
% sodium 51 to 70	32	5	1380 ± 90	63 ± 1	0.76 ± 0.26	381 ± 44	547 ± 94	88 ± 2
% sodium over 70	33	5	2950 ± 890	83 ± 1	1.03 ± 0.04	368 ± 114	534 ± 106	102 ± 8

TABLE 5

ANALYSES OF 1-1 AQUEOUS EXTRACTS OF VIRGIN AND CULTIVATED SOILS IN AREA OF LOW MAGNESIUM CONTENT

Plot	Sample Depth	Electrical Conductivity at 25° C	pH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{--}	Cl^{-}	NO_3^{-}
no.	feet	micromhos/cm		m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l
1	0-2	18180	7.7	13.7	2.6	190	3.4	3.1	117	84.0	2.6
	2-4	5850	8.1	1.1	0.5	53.8	2.1	1.8	30.3	25.5	0.6
	4-6	2320	8.1	0.4	0.2	19.7	1.1	1.9	11.9	8.0	0.3
1a	0-2	368	7.8	0.7	0	2.8	0.9	1.4	1.2	0.9	0.5
	2-4	369	8.0	0.4	0.3	2.6	0.9	1.9	1.0	1.0	0.2
	4-6	296	8.2	0.3	0.3	1.3	0.9	1.4	0.5	0.7	0.2
2	0-2	8770	7.1	36.6	10.5	46.3	3.3	0.8	29.1	67.8	0.5
	2-4	4200	7.0	12.1	4.9	27.2	1.4	0.8	9.8	34.6	0.5
	4-6	3170	7.2	5.7	3.4	19.9	1.0	0.7	4.5	24.1	0.3
2a	0-2	270	8.0	0.5	0.1	1.9	0.9	1.7	0.7	0.7	0.1
	2-4	549	7.9	0.3	0.1	4.1	0.1	1.9	1.8	1.7	0.1
	4-6	1230	7.7	1.7	0.2	7.9	0.2	1.5	5.6	4.0	0.3

Plot 1, Virgin soil; 1a, soil from adjacent citrus orchard (Sec. 13, T8S. R8E)
Plot 2, Virgin soil; 2a " " adjacent vineyard (Sec. 34, T7S. R8E)

Low magnesium waters and soils

As mentioned previously, ground waters in Coachella Valley are generally low in magnesium. This is especially true of the western portion of the lower part of the Valley. Studies made on the water soluble and replaceable magnesium present in samples of soil collected from cultivated and virgin fields revealed a very low magnesium content. These data are reported in Table 5. It is indicated that the cultivated fields have a lower content than the adjacent virgin soil. Analysis of leaves from a citrus orchard and vineyard showed a lower magnesium content than leaves from plantings on soils higher in magnesium.

While these data do not prove that crop yields are affected by the low magnesium content, they are reported as factual information regarding soil and water conditions. The supplemental water supply which is to be brought to the Valley is relatively high in magnesium.

GROUND WATER LEVELS

The Coachella Valley County Water District made available data on ground water levels which they have collected more or less continuously since 1919. These wells have been located and their approximate ground surface elevations obtained from the 2-foot contour maps of the U.S. Bureau of Reclamation. Level surveys have been made to most of those wells located beyond the boundary of the area mapped by the Bureau of Reclamation. Information on well depths and depths of perforations was obtained wherever possible.

At first, all observations were made on irrigation or domestic wells, but in 1927, a number of perforated cased wells, 15' to 30' in depth, were installed. These are in the trough of the Valley where the water table is relatively near the ground surface. Because of the impervious nature of some soil strata, and because of the pressure losses in any water moving upward, the level of these shallow wells is considerably below that of the deeper wells. In fact, with adjacent irrigation wells in the lower trough of the Valley it is usually found that the static pressure increases with the depth of the well.

A selected list of wells measured by the District is found in Table 6. This table does not include a number of wells measured in the 1920 to 1927 period but since lost, and other wells of which measurements were discontinued before any significant records were obtained. All wells measured from 1927 to 1939 are included. Table 7 gives a selected list of observations for the wells listed in Table 6. The readings selected are 3 to 5 years apart, and are taken for that period of the year when irrigation demands are least (January or February).

The elevations of the water table as of January, 1939, are shown on Figure 1. Shown also are the approximate limits of flowing wells at that time. Two abandoned wells, which may be partially plugged or relatively shallow, are omitted from the data from which ground water contours were located. These wells are Nos. 4-7-31 and 7-9-7b.

Twenty-one representative wells scattered over the Valley were selected on the basis of continuity of record and geographical position, and all records available for these were plotted as shown in Figure 3, (page 26)

Since irrigation is normally a summer operation, ground water basins are usually not affected by pumping during the winter months. Water levels then reflect the natural regime of the ground water except as modified by previous withdrawals of temporarily "stored" water. If the basin is not artesian, and the average specific yield of the soils is known, any change in water level from one winter to another can be used to estimate quantitatively the change in storage. If the basin is artesian, changes in levels from one winter to another may indicate only a change in pressure. Such changes in pressure would be caused by certain changes in storage over only a part of the basin. The differentiation between actual storage loss or gain and change in pressure is at best only a guess.

In Coachella Valley the ground water is artesian in nature, and considerable pumping is done through the winter months. During the winter water is now pumped at about one-fourth the summer rate. Winter pumping, however, is becoming more common because of the increasing acreage of crops such as dates and grapefruit which are irrigated the year around, and because of the decrease in the last 20 years of such crops as cotton and onions, which are not planted until early Spring. Further, there has been a steady increase in the cropped acreage in the Valley, so that ground water withdrawals have become greater. It should be obvious, therefore, that the continued drop in water levels in Coachella Valley has been primarily a reflection of increased use, and not neces-

TABLE 6

DESCRIPTION OF WELLS MEASURED FOR STATIC WATER LEVELS
BY COACHELLA VALLEY COUNTY WATER DISTRICT

Well	C.V.C. W.D.	Location in Section indicated	Depth of Well	Reference Point (R.P.) Elev.	Above Ground	Description
1	2	3	4	5	6	7
no.	no.		feet	feet	feet	
"DEEP" WELLS						
3-5-28	717	Nr.NE cor. NW $\frac{1}{4}$ of NW $\frac{1}{4}$	...	+651.7	0.0	Top concrete base
4-5-29	660	NW cor. of SE $\frac{1}{4}$	...	+324.6	1.2	
4-6-8	716	Ctr. of section	...	+383.1	1.0	Bottom of pump base
4-6-18	644	400' W & 1820'S of ctr. sec.	400	+231.6	0.0	Hole in pump base
4-6-19	328	In NE $\frac{1}{4}$	...	+212.6	0.0	Abandoned
4-6-27	715	300' E & 1300' N of SW cor.	1134	+164.	0.0	Bottom pump base
4-6-30	645	2500' W & 1300' S of NE cor.	...	+284.5	0.0	Top casing. Abandoned
4-7-31a,b	641	530' E & 2640' N of SW cor.	...	+117.	0.0	Top 12" casing. Abandoned
4-7-32	640	Nr. NW cor. of SE $\frac{1}{4}$ of NW $\frac{1}{4}$	...	+ 86.0	0.0	
5-5-2	659	Nr. SW cor. of NW $\frac{1}{4}$ of SE $\frac{1}{4}$	240	+245.2	0.0	
5-5-12	648	Nr. ctr. of N $\frac{1}{2}$ of SE $\frac{1}{4}$	...	+224.0	2.7	Abandoned
5-6-6	647	200' E & 500' N of SW cor.	...	+224.0	0.6	Top casing
5-6-18a	649	435' E & 220'N of SW cor. of NW $\frac{1}{4}$	...	+228.2	-5.5	Top casing in pit Abandoned
5-6-18b	719	55' E & 82'S of SW cor. of NW $\frac{1}{4}$ of SE $\frac{1}{4}$	...	+212.9	0.2	Conc.edge pit.3.9' above top casing. Abandoned
5-6-21d	347	SW $\frac{1}{4}$ of SW $\frac{1}{4}$ of NE $\frac{1}{4}$	330	+190.4	0.4	Top casing. Abandoned
5-6-22f	658	100' E & 530' N of SW cor. of SE $\frac{1}{4}$	302	+183.7	0.7	Remove plug. Meas. in disch. pipe
5-6-36	651	800' W & 375' N of SE cor. of NE $\frac{1}{4}$ of SW $\frac{1}{4}$	206	+ 47.7	0.5	Conc. floor
5-7-4	639	1750' W & 10'S of NE cor.	...	+ 47.	0.0	Abandoned
5-7-8	642	1130'W & 380'S of NE cor. of SE $\frac{1}{4}$	...	+ 54.	0.0	Top casing. Abandoned
5-7-10	638	2110' W & 1300' N of SE cor. of NE $\frac{1}{4}$	...	+ 23.	0.0	
5-7-13a	637	530'E & 790'S of NW cor.	...	-10.	1.5	Top conc. curb on N.
5-7-13b	Old 47	SE $\frac{1}{4}$	600	-20.7	0.0	Top 2" casing. Abandoned
5-7-18	656	Nr.NW cor. of SW $\frac{1}{4}$ of SW $\frac{1}{4}$	140	+149.3	1.7	Top casing
5-7-20a	655	2640' E & 1321'S of NW cor.	...	+ 94.3	0.0	Top casing
5-7-20b	654	300' E & 450' N of SW cor.	...	+ 84.9	3.6	Top casing
5-7-22b	Old 24	SE $\frac{1}{4}$ of NW $\frac{1}{4}$	183	+ 11.	1.7	Top casing. Abandoned
5-7-26b	...	At SE cor. of SW $\frac{1}{4}$	704	- 10.8	0.0	Conc. floor. Abandoned sanded to 600'.
5-7-30b	652	950' E & 410'S of ctr. sec.	116	+ 60.	0.0	Top wood clamp on casing.
5-7-34c	634	1210' W & 2530' N of SE cor.	114	+ 26.5	2.2	Top casing
6-7-8a	636	3860' W & 50'S of NE cor.	...	+ 26.	0.8	Stud bolt
6-7-8b	635	NW $\frac{1}{4}$ of NW $\frac{1}{4}$	123	+ 23.3	0.6	
6-7-16	Old 95	SW $\frac{1}{4}$ af SW $\frac{1}{4}$	...	- 19.1	...	Top casing
6-7-20	631	140' W & 60' S of NE cor.	...	-10.	0.0	Top casing
6-7-22	630	2150' W & 170'S of NE cor.	1530	-42.	0.0	Bottom pump base
6-8-2	713	1270'E & 2610' N of SW cor.	...	-56.	0.0	
6-8-5	721	1200' W & 1180' N of SE cor.	640	- 80.	1.0	Hole in pump
6-8-11b	620	690'E & 1200' N of SW cor.	400	-104.	2.0	
6-8-19a	628	300'E & 120S of NW cor.	1415	- 84.	0.0	Top of bushing in top 6" T.
6-8-19b	626	1110' W & 1905' N of SE cor.	...	-110.6	0.5	
6-8-21	378	NW cor.	517	-107.	6.1	Faucet - SE cor house
6-8-23a	619	670' E & 70'S of NW cor.	...	-121.	1.0	
6-8-23b	712	340'W & 960'N of SE cor.	...	-113.	0.0	
6-8-32a	708	1160'W & 1260'N of SE cor.	...	-134.	2.0	At $\frac{1}{4}$ - $\frac{1}{2}$ reducer 1.2' above ground
6-8-32b	707	1260'W & 1220'N of SE cor.	1025	-132.	4.0	Faucet on N. side house
6-8-36	706	100'E & 2500'N of SW cor.	1880	-151.	2.2	At outlet valve. Abandoned
7-7-1	622	Nr. NW cor. of NE $\frac{1}{4}$	...	-113.	0.2	
7-7-3	623	600' W & 660'S of NE cor.	...	- 71.	1.1	

(continued on next page)

DESCRIPTION OF WELLS MEASURED FOR STATIC WATER LEVELS

BY COACHELLA VALLEY COUNTY WATER DISTRICT

Well	C.V.C. W.D.	Location in Section indicated	Depth of Well	Reference Point (R.P.) Elev.	Above Ground	Description
1	2	3	4	5	6	7
no.	no.		feet	feet	feet	
"DEEP" WELLS (Continued)						
7-8-3	621	Nr. NW cor.	...	-154.	0.0	
7-8-7d	601	Nr. SE cor.	196	- 90.	0.3	
7-8-17	602	770' W & 730'S of NE cor.	1100	-115.	0.6	Pump base
7-8-18	705	1340'E & 370'S of NW cor.	770	- 71.	2.0	Top reducer on S side
7-8-21	610	1280'W & 1660'S of NE cor.	...	- 91.	0.0	
7-8-34a	603	450'E & 930'S of ctr. sec.	895	- 85.	0.0	Bottom pump base
7-8-34d	606	830'E & 340'N of ctr. sec.	...	- 91.	0.0	
7-8-35c	604	2370'E & 360'N of SW cor. of NW ¼	410	-152.	6.5	
7-8-35d	704	2000'E & 270'N of SW cor.	...	-151.	0.0	
7-8-35e	703	2530'E & 1480'N of SW cor.	1284	-161.	0.0	Shut off valve on N.
7-9-7	615	1710'E & 1540'S of NW cor.	...	-185.	0.7	Old well at 2 palms
7-9-8	374	Nr. SW cor.	1511	-192.	...	¼" cock on top of plug.
7-9-20	613	2640'E & 240'S of NW cor.	500	-206.	2.0	
7-9-26	711	1580'W & 660'N of SE cor. of NE ¼	...	-199.	0.0	Top casing. Abandoned
7-9-30	614	90'E & 40'S of NW cor. of SW ¼	...	-215.	0.0	
7-9-33	710	400'E & 270'S of NW cor. of SW ¼	...	-233.	1.0	
8-8-4b	702	1050'W & 110'S of NE cor.	...	- 12.	-1.0	Top ½" pipe in plug
8-8-11c	607	2110'W & 690'S of NE cor.	950	-149.	1.0	
8-8-24b	701	1340'W & 280'S of NE cor.	910	-155.	0.0	Top concrete base
8-8-24c	700	80'W & 80'S of ctr. sec.		-110.	0.6	
8-9-33f	609	50'E & 260'N of SW cor.	...	-133.	1.0	Pump base at air line
SHALLOW GROUND WATER WELLS:						
6-8-4A	57	NE cor.	20.9	- 83.6	...	Mud at 17' in 1939
6-8-16A	4	5'W & 34'N of SE cor.	31.5	-120.	...	Shifted to SW cor. SE ¼ of SE ¼ in 1939
6-8-18A	2	30' W & 32' N of SE cor.	31.1	- 97.	0	...
6-8-20A	3	32'E & 230'S of NW cor.	23.0	-111.8	...	At NW cor sec 21 up to 1933
6-8-21A	7	28'W & 32'N of SE cor.	32.0	-133.8	0.7	...
6-8-25A	14	30'E & 40'N of SW cor.	30.9	-147.	...	Nr. NE cor sec 35 to 1939.
6-8-26A	8	50' NE of SP on N sec. line	30.6	-136.	...	...
6-8-32A	9	35'E & 18±' S of NW cor.	25.5	-116.	...	Surface water enters. 1939
6-8-33Aa	10	22'SE of prop cor at NW cor.	11.0	-136.	...	...
6-8-33Ab	11	43'E & 44'S of NW cor. NE ¼	17.0	-142.	...	...
6-8-34A	12	2'E & 8'S of fence at NW cor.	22.	-145.	...	...
6-8-36A	18	SW cor.	18.8	-160.7	0.4	At NE cor sec 2 (7-8) to 1939
7-8-2A	22	27'W & 20'N of SE cor.	25.5	-174.	...	...
7-8-8A	20	30'E & 2'S of NW cor.	25.6	-136.7	0	R.P. changed. 1927
7-8-10Aa	21	2'E of NW cor. (Rd. 110±' E)	17.8	-164.	0.4	...
7-8-10Ab	25	74'N of SW cor.	22.0	-166.	0	...
7-8-11A	26	40'N of SW cor.	17.0	-180.3	1.2	...
7-8-23A	30	54'W & 28'S of NE cor.	22.0	-194.6	0.7	Cleaned out 9-3-38
7-8-35A	38	32'W & 30'S of NE cor.	18.5	-189.9	...	...
7-9-18Aa	27	42'E & 34'S of NW cor.	20.3	-192.0	0	...
7-9-18Ab	28	43'W & 37'S of NE cor.	...	-193.	0	Destroyed
7-9-20A	33	2'SE of fence cor. at NW cor.	17.2	-207.1	0.4	
7-9-22A	37	40'NE of SW cor 25' NE fence	26.1	-209.6	0	
7-9-27A	42	1'W of SE cor.	12.7	-225.0	0.3	
7-9-33A	45	At NW cor. of SW ¼	...	-234.	...	Destroyed. 1938
7-9-36A	46	2'S of NW cor.	20.1	-218.3	0.5	...
8-8-13A	51	At NE cor.	16.0	-206.0	0.4	...
8-9-7A	47	60'E & 27'S of NW cor.	12.9	-210.6	...	...
8-9-20A	54	1100'E & 300'S of NN cor. SW ¼	15.7	-207	...	...

(concluded on next page)

DESCRIPTION OF COLUMNS: TABLE 6 (concluded)
Column No.

1. First number is township south of San Bernardino Base, second number is range east of S. B. Meridian, third number is section. "A" following designates shallow ground water wells, usually 15 to 25 ft. deep. Lower case letter following differentiates two or more wells in one section.

2. Number used by Coachella Valley County Water District.

3. Location of well in section.

4. Depth of well in feet.

5. Elevation in feet of reference point (R.P.) above (+) or below (-) sea level, U.S.G.S. datum. Elevations shown only to the nearest foot were estimated from U. S. Bureau of Reclamation topographic maps (contour interval = 2 ft.). Figures shown to 1/10 of foot actually determined in field. Elevation of R.P. for well 4-6-8 estimated from Metropolitan Water District of Southern California map H-339-4.

6. Feet R.P. above average adjacent ground surface as established by Water District in 1939 to correlate with topographic maps. Not always the same as immediate ground surface at well.

7. Description of R.P. for "deep" wells. Remarks for shallow ground water wells (R.P.'s all top of pipe).

sarily a reflection on the adequacy of the supply or an indication of any great change in storage.

Inspection of Figure 3 will reveal that annual fluctuation of water levels, as well as rate of drop, increases with distance down the Valley. This indicates that the principal effect of ground water withdrawals has been to lower the downstream levels, thereby reducing the natural losses in the lower basin. Not until the period of 1930 to 1935 were the levels at the upper end of the agricultural area affected, and the drop in those levels corresponded with large-scale developments in the Indian Wells and Edom districts, upstream.

Information in the above paragraph might be summarized as follows:

1. Appreciable ground water withdrawals have the long-range effect of lowering the levels in all wells downstream from the wells in question.

2. Ground water levels upstream from a well or group of wells are not significantly affected by withdrawals from those wells except within a limited radius of those wells.

3. The wells at the upstream end of the developed areas do not reflect annual fluctuations in ground water recharge.

In regard to the shallow observation wells, no detailed interpretation has been attempted because there is evidence that at least some of them did not correctly reflect the actual piezometric surfaces of the aquifers intercepted.

Although the above discussion would indicate that the supply is largely adequate for the area developed up to 1936-39, and probably for a greater area, there is an economic question involved. As more land is irrigated and water levels drop, it is necessary to make additional capital outlays in deepening wells, drilling new wells, and installing new pumps. Further, as the pumping lift increases, the cost of pumping increases. There follows a natural tendency to specialize more on crops whose returns justify higher water costs, to improve methods so as to cut down on waste of water, and, sometimes, to abandon unprofitable enterprises, or to seek other water supplies. Also, as wells become closer together, mutual interference magnifies the increase in pumping lift and decrease in yield beyond the arithmetic lowering of static levels.

In an investigation of irrigation applications, and of water requirements of various crops (11), it was found to be a common practice of farmers in the area to apply water in excess of crop requirements. Extensive records were obtained of water actually pumped, or taken from flowing wells, for irrigation of the various crops. By extending the rates of application so obtained to the Valley as a whole, using the crop survey, it appeared that in the period of 1936-39 total agricultural withdrawals from the ground water approximated 100,000 acre-feet per year, a portion of which is in excess of crop requirements. The excess applications should largely seep back to the water table, but savings would accrue from pumping less water and thus maintaining higher water levels. However, it must be understood that a certain amount of water in excess of crop requirements must always be applied to maintain a reasonably low salt balance, to provide a margin of safety, and to maintain adequate moisture in all parts of a stratified soil.

The crop and well survey, and other data (11), reveal that pumps in the Valley generally have a low load factor. Group or District operation of pumps should therefore result in economies.

The "safe yield" of a ground water basin is sometimes computed on the basis of measurements of water entering the basin minus the losses. Thus, run-off from the major streams is measured, and possibly proportional amounts are estimated for minor streams with corrections for surface run-off carried over the basin. Such estimates can hardly account for infiltration from streams above the measuring points, or for infiltration directly from precipitation, on any rational basis. Invariably such estimates, even if carefully made, are low.

Some measurements of flow have been made on most streams entering Coachella Valley. Their usefulness has two important limitations. First, they represent only periodical gagings, which gagings were not made during flash floods when a great proportion of run-off probably occurs. Second, it appears that opportunity for significant amounts of infiltration exists above the points of measurement.

TABLE 7

ELEVATIONS OF STATIC WATER SURFACE OF WELLS MEASURED BY

COACHELLA VALLEY COUNTY WATER DISTRICT

(Measurements for period 1920 to 1947, made during month indicated. Measurements made in January and February normally at highest elevation for year and least affected by pumping. U.S.G.S. sea level datum for elevations.)

	Elevation of water surface (above or below sea level)								
Well	Jan. 1920	Feb. 1923	Jan. 1927	Jan. 1930	Jan. 1935	Jan. 1939	Jan. 1944	Jan. 1947	REMARKS
1	2	3	4	5	6	7	8	9	10
no.	feet	feet	feet	feet	feet	feet	feet		
3-5-28	..	..	..	..	598.1	585.3	590.0	544.5	
4-5-29	223.0	226.3	226.0*	..	..	..	..	..	March 1927. Nov. 1918 = 224.6
4-6-8	..	..	..	..	159.9	155.2	151.1*	121.1	*Nov. 1943.
4-6-18	168.0*	168.9	167.8	170.5	167.1	..	..	..	*Nov. 1920
4-6-19	159.8	161.0	..	..	..	..	..	..	
4-6-27	..	..	..	..	..	113.4	109.8	..	
4-6-30	157.4	158.4	158.6	159.3	156.0	..	..	..	Nov. 1913 and Nov. 1918 = 154.5
4-7-31a	..	..	42.0	41.4	39.7	37.8	..	..	
4-7-31b	..	..	..	..	..	..	30.6	23.3	
4-7-32	58.3*	58.0	55.7	53.3**	51.2	..	..	..	*Apr. 1920, **Feb. 1930
5-5-2	165.6	166.8	166.9	168.5	158.7	155.0	..	..	
5-5-12	146.2*	147.1	146.6	147.3	..	..	..	..	*Dec. 1920
5-6-6	142.1*	142.9	142.7	143.9	144.8	138.1	131.2	..	*Dec. 1920
5-6-18a	139.2	140.5	139.7	141.0	..	..	..	..	
5-6-18b	..	..	..	..	141.4	138.7	143.2	..	
5-6-21d	105.1	..	..	..	..	..	..	..	
5-6-22f	..	..	109.9	110.8	105.3	101.7	97.8	93.7	
5-6-36	..	..	-21.3	-24.2	..	-34.5	-40.8	-52.3	
5-7-4	32.3*	30.8	27.2	28.3	21.5	22.8	..	..	*March 1920.
5-7-8	28.4	27.4	24.6	19.9	18.3	14.1	9.5	4.8	
5-7-10	..	..	-5.8	-10.4*	-11.0**	Caved	..	..	*March 1930.**Feb. 1935
5-7-13a	-7.0	-23.4	-24.2*	-30.8	-34.4	-35.1	-45.0	-53.0	*Feb. 1927
5-7-13b	Flowing	-23.7	..	..	..	..	..	..	Flowing Apr.1905 and Nov.1918.Sept.1917 = -23.7
5-7-18	52.8	52.1	49.5	47.7	43.9	..	..	..	Nov. 1918 = 49.3'
5-7-20a	16.8	15.4	11.5	8.7	5.3	0.7	-4.8	..	
5-7-20b	14.6	13.1	9.4	3.0*	3.3	-6.1	-14.7	..	*Feb. 1930
5-7-22b	-20.2	-22.0	..	..	..	..	..	..	Sept. 1917 & Nov. 1918 = -20.0'
5-7-26b	..	..	..	..	-58.8	-58.8*	..	..	*Feb. 1939
5-7-30b	5.8	4.3	-2.5	-3.9	-8.1	-13.0	..	..	
5-7-34c	-27.7	..	-34.5	-38.7	-44.2	-46.7	-52.5	..	Nov.1908 = -24.5'
6-7-8a	..	..	-38.5	-42.0	-46.5	-51.3	-55.6	-65.3	
6-7-8b	-34.3	-36.2	..	..	..	..	..	..	Apr. 1905 = -24.7'
6-7-16	-77.7	..	..	..	..	..	..	..	
6-7-20	-64.6	-68.7	-73.7	-76.9	-80.6	-84.5	Caved	..	
6-7-22	-48.0	-48.6	-50.6	-52.9	-56.3	-61.0	-62.3	-69.9	
6-8-2	..	..	..	..	-107.3	-110.7	..	..	
6-8-5	..	..	..	..	..	..	-108.3	-111.8	9-30-38=-120.0'
6-8-11b	..	..	-114.0	115.6	-118.2	-123.0	-127.5	-136.5	
6-8-19a	-61.1	..	-66.8	-66.4	-73.3	Flowing	Flowing	-83.6	
6-8-19b	..	..	-87.5	-77.1	-97.1	-101.0	-101.4	-105.6	
6-8-21	-98.9	-100.2	..	..	..	..	..	..	
6-8-23a	-119.3	..	-126.2	-128.4	-132.2	-148.6	..	..	
6-8-23b	..	..	..	..	-152.4	-152.8	..	..	
6-8-32a	..	..	..	..	-130.0	-131.5	-137.0	..	
6-8-32b	..	..	..	..	-98.8	-112.4	-110.0	-118.2	
6-8-36	..	..	..	..	-133.2	-135.8	-135.0	-151.0	
7-7-1	..	..	Flowing	-114.6	-118.6	..	..	..	
7-7-3	..	..	..	-82.4	-114.6	..	..	-131.0	

(concluded on next page)

TABLE 7 (concluded)

ELEVATIONS OF STATIC WATER SURFACE OF WELLS MEASURED

BY COACHELLA VALLEY COUNTY WATER DISTRICT

	Elevation of water surface (above or below sea level)								
Well	Jan. 1920	Feb. 1923	Jan. 1927	Jan. 1930	Jan. 1935	Jan. 1939	Jan. 1944	Jan. 1947	REMARKS
1	2	3	4	5	6	7	8	9	10
no.	feet	feet	feet	feet	feet	feet	feet		
7-8-3	..	..	-112.5	Flowing	-134.7	..	Flowing	..	
7-8-7d	..	..	-134.9	-140.9	-141.4	-128.8*	..	-156.0	*Probably adjacent deeper well
7-8-17	..	..	-127.0	-130.5	-136.2	-141.1	-145.2*	-157.0	*December 1943
7-8-18	..	..	..	..	-135.4	-137.2	-147.4	-154.5	
7-8-21	..	..	-131.8	-134.7	-142.4	-147.8	-155.2*	-179.0	*December 1943
7-8-34a	..	..	-135.4	-141.0	-149.6	-154.0	-159.7	..	
7-8-34d	..	..	-141.8	-143.4	-151.7	-156.6	-163.4	-168.5	
7-8-35c	..	..	-144.8	-144.4	-154.6	-161.6	..	..	Casing cut 200-202, 408-410
7-8-35d	..	..	..	..	-157.8	-161.5	..	..	
7-8-35e	..	..	..	..	-151.4	-155.3	-164.5	-173.0	
7-9-7	..	..	-129.6	-147.7	-160.3	..	-166.5	..	
7-9-8	-151.6	-158.2	..	..	..	..	..	..	Well cleaned in 1939
7-9-20	-156.3*	-163.0	-169.0	..	-183.3	-186.5	-189.8	-203.7	*Feb. 1920
7-9-26	..	..	..	..	..	-200.9	-199.0	-203.8	N.G. Surface run-off flows into well (1939)
7-9-30	..	..	-182.7	-176.6	-189.3	-187.0	-193.0	-191.2	
7-9-33	..	..	..	..	-192.5	..	..	..	
8-8-4b	..	..	..	..	-149.9	-155.8	-164.1*	..	*December 1943
8-8-11c	..	..	-136.2	..	-157.6	-163.7	-171.1	..	
8-8-24b	..	..	..	..	-169.2	-173.5	-182.4	-191.2	
8-8-24c	..	..	..	..	..	-175.5	-183.9	-191.2	
8-9-33f	..	..	-155.8	-165.9	-177.2	-182.2	-190.2	-195.3	
6-8-4A	..	..	..	..	-103.6	-96.9	..	..	
6-8-16A	..	..	-129.7	..	-137.9	-142.4	-148.1*	Mud	*November 1943
6-8-18A	..	..	-109.2	..	-118.8	-123.4	Dry	..	Location shifted in 1933
6-8-20A	..	..	-121.7	..	-127.1	Dry	Dry	..	
6-8-21A	..	..	-141.2	..	-147.0	-143.0	-157.8	-160.7	
6-8-25A	..	..	-161.4	..	-170.2	-172.6	Dry	..	
6-8-26A	..	..	-146.9	..	-157.0	-159.8	-165.0*	..	*Nov. 1943
6-8-32A	..	..	-126.3	..	-133.8	..	Dry	Dry	
6-8-33Aa	..	..	-139.8	..	..	-145.0	Dry	..	
6-8-33Ab	..	..	-145.0	..	..	-155.6	Dry	..	
6-8-34A	..	..	-150.1	..	-156.8	-151.0	-148.7*	-151.5	*Nov. 1943
6-8-36A	..	..	-166.5	..	-178.5	..	Dry	Dry	
7-8-2A	..	..	-182.6	..	-188.8	-190.6	Dry	Dry	
7-8-8A	..	..	-144.9	..	-156.0	-159.4	Dry	..	
7-8-10Aa	..	..	-169.5*	..	-176.4	Dry	Dry	Dry	*Feb. 1927
7-8-10Ab	..	..	-174.7	..	-181.3	-185.1	Dry	Dry	
7-8-11A	..	..	-187.8	..	-191.7	-194.3	Dry	Dry	
7-8-23A	..	..	-203.1	..	-204.8	-207.2	-216.1*	Mud	*Nov. 1943
7-8-35A	..	..	-201.4	..	-202.5	Dry	Dry	Dry	
7-9-18Aa	..	..	-199.5	..	-203.2	-204.8	Caved	..	
7-9-18Ab	..	..	-204.7	..	-208.0	..	-206.1*	-214.0	*Dec. 1943
7-9-20A	..	..	-215.0	..	-217.4	-219.7	Mud	Dry	
7-9-22A	..	..	-219.6	..	-224.2	-217.2	-223.8*	..	*Nov. 1943
7-9-27A	..	..	-233.6	..	-234.2	-234.8	-236.0*	Dry	*Nov. 1943
7-9-33A	..	..	-237.6	..	-239.2	..	..	..	
7-9-36A	..	..	-234.3	..	-234.5	-235.5	-236.6*	-236.5	*Nov. 1943
8-8-13A	..	..	-211.2	..	-216.3	-217.4	-221.8*	-213.6	*Nov. 1943
8-9-7A	..	..	-218.5	..	-218.8	-219.2	-222.4*	Mud	*Nov. 1943
8-9-20A	..	..	-219.7	..	-209.4	Dry	-221.8*	-220.3	*Nov. 1943

Irrigation canals in Coachella Valley.
(credit: U. S. Bureau of Reclamation)

TABLE 8

CHEMICAL COMPOSITION OF WELL WATERS USED ON THE FLOODING PLOTS AND OF COLORADO RIVER WATER USED IN LABORATORY EXPERIMENTS.

Tract	Water Source	Electrical Conductivity at 25° C	Ca	Mg	Na	CO_3	HCO_3	SO_4	Cl	NO_3	Na ‡
no.		micromhos/cm	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	per cent
1.	Well	245	0.30	Trace	1.92	Trace	1.39	0.53	0.34	0.0	87
2.	Well	246	0.75	0.10	1.62	0.04	1.51	0.66	0.31	0.06	66
3.	Well	253	0.25	Trace	2.00	1.35	0.15	0.58	0.36	0.0	89
4.	Well *	242	0.63	0.11	1.61	Trace	1.58	0.47	0.28	0.04	69
		254	0.35	0.03	2.05	0.25	1.29	0.52	0.39	0.03	84
5.	Well	254	0.25	Trace	2.17	1.47	0.05	0.61	0.34	0.0	90
6.	Colorado River†	980	4.78	1.74	3.57	(2.46)		5.73	2.05	0.08	34

* Analyses are not of water used, but of two nearby wells of similar depth.

† Analysis of sample collected from East Side Canal in Imperial Valley in February, 1939.

‡ Sodium as of total cations.

SALT REMOVAL FROM VALLEY SOILS

Leaching

Plans for the expansion of agriculture in Coachella Valley through the use of imported Colorado River water contemplate the utilization of a large portion of the fine textured soils in the trough of the Valley. As previously mentioned, these soils are commonly saline. To reclaim this area will require the leaching of large amounts of salts from the soil profile, and the maintenance of the water table at a safe depth. At present the ground water table is usually in excess of 10 feet below ground surface. The decrease in artesian pressure, resulting from increased pumping, has tended to lower the water table in most parts of the Valley. The use of imported water will probably reverse this condition.

The bringing of Colorado River water to this Valley will permit use of methods of leaching and flushing which are not now practical with pump flows; and provide a high calcium ratio water on the soils which have become dispersed.

Whether it is economically feasible to make the heavy saline soils productive is beyond the purview of this study, but any plan which does not recognize the need for good drainage and the maintenance of a ground water table well below the rooting depth is unsound. We have attempted, however, to secure some field and laboratory data on rate of water percolation into soils of medium to fine texture, and to measure the amount of leaching resulting therefrom. Five separate tracts were selected for this study. The waters used were of low salt content, but of high sodium percentage. Table 8 contains data on the well waters used, together with an analysis of the Colorado River water used in the laboratory tests.

Experiments on leaching saline soil

Tract 1. (Camelthorn)

Location: SE$\frac{1}{4}$ of NE$\frac{1}{4}$ of SW$\frac{1}{4}$, section 12, T.7S., R.8E. (See Figure 1.)

Soil classification: Indio very fine sandy loam.

Depth of water table below ground surface: 14 to 18 feet.

Land had been farmed at one time.

Several experiments were conducted at this location, as follows:

a. A plot 10 ft. x 25 ft. was flooded 9 times between March 3 and 20, 1937; amounts of water applied were not measured but water passed down to the water table at 14 feet. Comparison of the electrical conductance of aqueous extracts from soil samples taken before and after flooding is shown in Table 9.

TABLE 9.

TRACT No. 1 (a), MARCH, 1937.

ELECTRICAL CONDUCTIVITY OF 1-5 AQUEOUS EXTRACTS OF COMPOSITED SOILS SAMPLES TAKEN BEFORE AND AFTER FLOODING.

Depth	Electrical Conductivity (at 25°C.) Before flooding	After flooding
feet	millimhos/cm*	millimhos/cm*
0-1	8.87	1.51
1-2	1.70	0.55
2-3	0.59	0.80
3-4	0.91	1.39
4-5	0.75	0.89
5-6	0.28	0.24
6-7	0.59	0.32
7-8	1.06	0.49
8-9	0.60	0.50
9-10	0.68	0.54
10-11	0.57	0.44
11-12	...	0.37

*Millimhos/cm. at 25°C is new electrical conductivity standard for soil extracts. To convert to K x 10^5, multiply by 100; to convert to micromhos/cm. multiply by 1000.

TABLE 10.

CHEMICAL COMPOSITION OF 1-5 AQUEOUS EXTRACTS* OF SOIL SAMPLES FROM A DATE GARDEN AND FROM AN ADJACENT NON-FARMED AREA, TRACT 1(b) June 15, 1938.†

Depth	Location ‡	pH	Ca	Na	CO_3	HCO_3	SO_4	Cl
feet			p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
0-1	1	9.0	1100	3622	0	144	6100	3018
	2	9.0	2350	11982	Tr.	397	14086	10827
1-2	1	9.9	20	1202	120	198	990	1163
	2	9.0	690	3207	60	320	7228	2254
2-3	1	10.1	10	1035	360	31	1087	710
	2	10.1	50	782	300	198	838	373
3-4	1	10.0	10	920	180	183	898	763
	2	10.1	30	1280	360	76	1704	231

* By weight: 1 part dry soil to 5 parts water.

† Data provided by D. E. Bliss and Bert Laurence, Citrus Experiment Station, Riverside.

‡ (1) Irrigated date garden, (2) adjacent unfarmed area.

b. On June 15, 1938, soil samples were taken from an irrigated area in a young date planting just west of plot (a) and in an adjacent area of virgin soil. The water soluble salt content of the soil from the two locations is shown in Table 10.

c. In the period Dec. 9, 1938, to March 1, 1939, a total of 6.3 feet depth of water was applied in 19 irrigations to a plot 20 x 20 ft. square adjacent to the plot described under (a). To minimize any border effect, an area surrounding the plot was flooded at each irrigation. At the conclusion of the treatment the soil was moist at all depths and the water table stood about 16 feet from the surface. Infiltration rates are shown in Figure 4, (page 27). Comparison of the average salt content of the soil in this plot before and after treatment is shown in Table 11.

The data indicate that the major portion of the soluble salts was near the surface of the soil and that flooding with local water, a low-salt high-sodium percentage water, caused a marked movement of salt through the soil profile. As will be shown later, Colorado River water, a high calcium content water, is a far more effective leachant than the well water used.

Tract 2. (Avenue 62)

Location: Approximately 50 ft. south of old reservoir in NW¼ of NW¼, section 2, T 7 S, R 8 E.
Soil classification: Indio clay loam.
Plot size: 20 ft. x 20 ft.
No evidence of water table found in sampling to 16 ft. depth.
Land had at one time been farmed.

TABLE 11.

TRACT 1c. DEC. 9, 1938 to MAR. 1, 1939

CHEMICAL COMPOSITION OF 1-5 AQUEOUS EXTRACTS FROM COMPOSITED SOIL SAMPLES TAKEN BEFORE (B) AND AFTER (A) FLOODING

Depth	Electrical Conductivity at 25°C		Ca		Mg		Na		CO_3 + HCO_3		SO_4		Cl		NO_3	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
feet	millimhos/cm		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l	
0-1	10.79	2.90	27.15	0.3	1.13	0.3	91.3	5.6	1.00	1.3	68.1	0.9	50.0	1.1	1.64	0
1-2	1.64	0.69	0.60	..	0.1*	1.2	14.88	5.8	2.18	2.1	7.03	2.8	5.98	0.6	0.13	0
2-3	1.15	0.55	0.3*	0.2	0.3*	0.5	10.17	5.3	1.70	3.3	6.46	3.6	2.50	0.3	0.04	0
3-4	0.96	0.95	0.3*	0.1	Tr.	0.6	9.08	4.2	4.69	4.4	2.82	3.3	1.58	1.3	0.04	0
4-5	0.44	0.56	0.2*	0.1	Tr.	0.1	3.93	5.0	1.63	2.2	1.75	2.1	0.77	1.1	Tr.	0
5-6	0.35	0.42	0.2*	0.1	0.2*	0.1	2.82	3.8	1.21	1.4	1.65	1.4	0.65	0.7	Tr.	0
6-7	0.64	0.55	0.85	0.1	0.23	0.1	4.76	4.6	0.87	1.2	3.94	2.3	1.15	1.2	0.02	0
7-8	0.64	0.71	0.4*	0.1	Tr.	0.1	5.67	6.2	2.34	2.2	2.36	2.5	1.38	1.6	0.02	0
8-9	0.63	0.53	0.44	0.1	0.2*	0.1	5.14	4.4	1.76	2.1	2.58	1.5	1.37	1.0	0.01	0
9-10	0.82	0.52	0.63	0.1	0.58	0.1	6.44	4.5	1.21	2.0	4.46	1.6	1.90	1.0	Tr.	0
10-11	0.65	0.41	0.59	0.2	Tr.	0.1	4.81	3.5	0.87	1.6	3.38	1.3	1.45	1.0	0.02	0
11-12	0.48	0.38	0.41	0.2	0.1	0.1	3.44	3.0	0.97	1.5	1.94	1.1	1.02	0.7	0.00	0
12-13	0.53	0.26	0.57	0.2	0.1	0.1	3.74	2.0	1.01	1.4	2.41	0.5	1.02	0.4	0.00	0
13-14	0.50	0.29	1.05	0.1	Tr.	0.1	3.32	2.4	0.75	1.6	2.74	0.7	1.00	0.4	Tr.	0
14-15	0.80	0.20	2.59	0.2	0.1	0.1	5.03	1.6	0.63	1.3	4.94	0.4	2.02	0.2	0.06	0
15-16	0.40	0.21	1.00	0.4	Tr.	0.1	2.57	1.4	0.67	0.9	1.96	0.8	0.85	0.2	0.02	0

* Semi-quantitative estimations by direct comparison with known amounts of the precipitate.

Irrigating a Coachella date garden.
(credit: U. S. Bureau of Reclamation)

TABLE 12.

TRACT No. 2, DECEMBER 9, 1938 - MARCH 4, 1939
CHEMICAL COMPOSITION OF 1-5 AQUEOUS EXTRACTS FROM COMPOSITED SOIL SAMPLES TAKEN BEFORE (B) AND AFTER (A) FLOODING (Wet to a depth of about 5 feet)

Depth	Electrical Conductivity at 25°C		Ca		Mg		Na		$CO + HCO_3$		SO_4		Cl		NO_3	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
feet	millimhos/cm		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l	
0-1	0.56	0.22	0.17	0.1	0.09	0.3	5.04	2.0	1.54	2.2	3.17	0.3	0.90	0	0.07	0
1-2	0.53	0.17	0.15	0.1	Tr.	0.2	4.98	1.8	1.86	1.4	2.57	0.2	0.65	0.1	0.05	0
2-3	0.47	0.24	0.12	0.1	0.05	0.1	4.30	2.6	1.41	1.8	2.16	0.2	0.80	0.1	0.03	0
3-4	1.23	0.41	0.1*	0.2	0.1*	0.2	11.32	4.2	2.88	2.6	5.47	0.3	2.75	0.1	0.05	0
4-5	0.44	0.57	0.12	0.1	0.13	0.8	3.88	5.1	1.17	1.2	1.91	2.8	0.75	0.8	0.04	0
5-6	0.45	1.07	0.12	1.4	0.0*	0.6	3.89	8.8	0.93	0.8	2.24	5.4	0.95	2.9	0.02	0
6-7	....	0.80	1.05	1.1	0.23	0.3	3.47	5.9	0.77	1.0	2.25	3.8	1.75	1.9	0.02	0
7-8	0.31	0.51	1.0	1.1	0.2*	0.3	1.87	3.2	1.12	0.9	0.4*	2.3	1.82	1.3	Tr.	0
8-9	0.19	0.22	0.4*	0.4	0.2	0.1	1.01	1.6	0.67	0.8	0.4*	0.8	0.41	0.4	0.04	0
9-10	0.18	....	0.1*	...	0.2*	...	1.41	...	0.63	...	0.35*	...	0.40	...	0.02	..
10-11	0.20	....	0.1*	...	0.2*	...	1.59	...	0.64	...	0.45*	...	0.40	...	0.03	..
11-12	0.22	....	0.1*	...	0.3*	...	1.67	...	0.72	...	1.2*	...	0.35	...	0.02	..
12-13	0.14	....	0.1*	...	0.2*	...	1.11	...	0.75	...	0.4*	...	0.20	...	0.01	..
13-14	0.09	....	0.15*	...	0.2*	...	0.62	...	0.65	...	0.1*	...	0.19	...	Tr.	..
14-15	0.08	....	0.25*	...	0.1*	...	0.96	...	1.17	...	Tr.	...	0.15	...	0	..
15-16	0.08	....	0.35*	...	0.2*	...	0.42	...	0.66	...	Tr.	...	0.24	...	0	..

* Semi-quantitative estimates by direct comparison with amounts of the precipitates.

In the period December 9, 1938, to March 4, 1939, a total of 6.7 feet depth of water was applied in 19 irrigations to the plot. To minimize border effect, an area surrounding the plot was flooded at each irrigation. At the conclusion of the experiment the soil under the plot was moist to a depth of only 5.5 to 6.5 feet. Apparently the soil at this depth was relatively impervious and the water applied moved off laterally through a more permeable stratum. Infiltration rates are shown in Figure 4. Comparison of the average salt content of the soil in this plot before and after treatment is shown in Table 12.

This soil was not as saline at the start of the test as that of Tract 1. Applications of well water caused a leaching of the salt from near the surface. A slight increase in salt content occurred in the stratum immediately below the porous layer through which water moved laterally.

Tract 3:

Location: Near North side of SW$\frac{1}{4}$ of NW$\frac{1}{4}$ of NE$\frac{1}{4}$, Section 17, T 7 S, R 9 E.

Soil Classification: Indio very fine sandy loam.

Depth of water table below ground surface: 13 feet before leaching, 10 to 13 feet after leaching.

Land had been farmed a few years prior to test.

In the period December 28, 1938, to March 2, 1939, a total of 9.4 feet depth of water was applied in 17 irrigations to a plot 20 x 20 feet square. As in the case of the other plots, an area surrounding the plot was flooded at each irrigation. Infiltration rates were higher for this plot than for the two other plots operated at the same time. Changes in the salt content of water extracts of soil samples taken before and after leaching treatment are shown in Table 13.

Leaching of salts from the highly saline surface soil into the ground water was readily accomplished in this trial. At the end of the test, the ground water, which stood at about 10 feet, was highly saline.

Tract 4:

Location: At SW corner of NW$\frac{1}{4}$ of NE$\frac{1}{4}$, Section 4, T 7 S, R 8 E.

Soil Classification: Indio very fine sandy loam.

Composite samples were obtained from two adjacent locations.

Plot 1 (irrigated land) had at one time been planted to alfalfa which at first did well, but after a few years the soil was reported to have "tightened-up" and a local high water table developed. Since then the artesian discharge of the wells had been allowed to flow over the land continuously to provide pasture. A dense growth of mesquite covered the area. The location where the soil samples were obtained had been flooded almost continuously for years.

Plot 2 ("virgin soil") is in the NW$\frac{1}{4}$ of Section 4, located within 50 feet of plot 1; it had never been cropped. Except for the differences arising from treatment, the soils are similar. Table 14 represents, then, salt content differences resulting from a long continued flooding with water from an artesian well.

The data indicate that the non-flooded soil through a depth of 10 feet was far more saline than the plot that had been flooded. Below 10 feet, where the soil is saturated, the salt conditions were similar in both plots.

Tract 5:

Location: S$\frac{1}{2}$ of NW$\frac{1}{4}$, Section 29, T 7 S, R 9 E.

Soil classification: Woodrow loam.

This location is within the area flooded by Salton Sea in 1907.

The soil is fine textured and has a high salt content. Table 15 gives an analysis of the salt content of water extract of soil samples collected in increments of 1/10 foot to a depth of one foot, together with an analysis of the salt crust which was approximately one-eighth inch thickness.

TABLE 13.

TRACT NO. 3, DEC. 28, 1938 - MARCH 2, 1939

CHEMICAL COMPOSITION OF 1-5 AQUEOUS EXTRACTS FROM COMPOSITED SOIL SAMPLES TAKEN BEFORE (B) AND AFTER (A) FLOODING.

Depth	Electrical Conductivity at 25°C		Ca		Mg		Na		$CO_3 + HCO_3$		SO_4		Cl		NO_3	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
feet	millimhos/cm		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l	
0-1	9.18	0.29	13.14	1.1	1.84	0.2	80.13	1.3	0.83	1.0	45.20	0.1	49.25	0.2	0.29	0
1-2	2.52	0.20	1.82	0.1	0.82	0.1	20.90	1.7	0.89	1.2	13.74	0	9.38	0.1	0.07	0
2-3	4.20	0.34	13.13	2.2	3.19	0.2	29.10	1.0	0.85	1.0	32.10	1.4	13.10	0.1	0.05	0
3-4	1.85	0.18	0.60	0.2	0.25*	0.1	16.04	1.6	1.17	1.1	7.67	0.6	8.45	0.1	0.06	0
4-5	1.31	0.28	0.15	0.1	Tr.	0.2	12.17	2.8	0.84	2.5	4.62	0.4	5.68	0.1	0.13	0
5-6	1.48	0.41	0.12	0.2	0.17	0.2	13.75	4.1	1.94	4.5	5.33	0.4	6.55	0.1	0.08	0
6-7	2.67	0.59	0.1*	0.2	0.2*	0.4	24.15	6.0	1.82	5.7	9.72	1.3	12.98	0.2	0.09	0
7-8	2.76	1.23	0.1*	0.2	0.1*	0.5	24.59	11.5	1.62	3.4	9.44	4.5	14.15	3.7	0.07	0
8-9	3.21	1.68	0.39	0.3	0.1*	0.5	29.78	2.9	1.84	2.9	11.15	6.4	16.70	5.8	0.16	0
9-10	3.36	2.26	0.1*	0.1	0.1*	0.3	32.01	20.9	1.51	1.6	11.34	8.0	18.95	9.9	0.19	0
10-11	3.32	3.12	0.2*	0.2	0.1*	0.2	30.84	29.0	1.49	1.4	11.35	10.7	18.00	15.4	0.06	0
11-12	3.36	2.80	0.4*	0.3	0.1*	0.4	30.75	26.4	1.68	1.4	11.51	8.8	18.05	14.0	0.11	0
12-13	2.74	2.83	0.37	0.3	0.1	0.3	25.08	26.8	1.11	1.5	9.85	8.3	14.50	14.5	0.1	0
13-14	2.71	2.96	0.29	0.3	0.1	0.3	24.69	27.9	1.21	1.4	9.81	8.9	14.28	15.1	0.06	0
14-15	2.60	2.98	0.26	0.3	Tr	0.4	23.93	27.8	1.15	1.3	9.80	8.8	13.48	15.4	0.06	0
15-16	2.51	2.77	0.30	0.3	Tr	0.4	22.34	25.7	1.09	1.5	8.80	8.1	13.20	14.3	0.06	0

* Semi-quantitative.

On Tract 5 are located ten large ponds, each with a gross area of 5 acres, which are flooded at least 5 months each year to provide duck hunting in the fall. Measurements were made of the average rate of drop of the water in these ponds after inflow was stopped for the year. Average values are shown in Table 16.

After the ponds had dried, soil samples were obtained from 4 ponds on the north side. Similar soil samples were obtained along an east-west line 40 feet north of the ponds. The latter samples represent unirrigated soil, but the entire area has been briefly inundated from time to time during heavy floods. A comparison of the salt content of the soil from the two locations described above is shown in Table 17.

The results of leaching are shown graphically in Figure 5, (page 28). Although experiments on the various plots indicate that, in most instances, the soil can be leached of excessive salts, the infiltration rate data obtained (Figure 4 and Table 16) are such as to raise doubts as to the practicability of maintaining, in all cases, reasonably low soil-water salt concentrations under the irrigation practices that could be expected to follow leaching, and with the present irrigation waters. This is in line with the general experience of farmers on these saline soils. Many enterprises have been abandoned, and those continuing do not appear too profitable.

In explanation of the infiltration data of Figure 4, it might be said that in general infiltration rates decrease with time. Rates are highest when water is first applied, the rates decreasing rapidly at first, and then more and more slowly until they become almost uniform.

TABLE 14

TRACT 4

CHEMICAL COMPOSITION OF 1-5 AQUEOUS EXTRACTS FROM COMPOSITED SOIL SAMPLES TAKEN ADJACENT TO FLOODED PLOTS (B) AND IN FLOODED PLOTS (A).

Depth	Electrical Conductivity at 25°C		Ca		Mg		Na		$CO_3 + HCO_3$		SO_4		Cl		NO_3	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
feet	millimhos/cm		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l	
0-1	15.22	0.41	56.2	2.1	6.9	0.5	105.6	1.0	1.7	2.3	109.6	1.2	55.7	0.4	0	0
1-2	9.33	0.20	6.1	0.6	1.2	0.1	74.0	0.9	1.2	1.6	28.2	0.3	47.8	0.0	0	0
2-3	5.03	0.15	1.4	0.7	0.3	0.2	38.1	0.3	1.1	1.3	11.8	0.2	25.8	0.1	0	0
3-4	2.97	0.17	0.8	0.5	0.3	0.4	22.1	0.3	1.2	1.4	6.7	0.2	14.4	0	0	0
4-5	0.88	0.09	0.2	0.4	0.1	0.4	5.0	0.2	1.1	0.9	2.2	0.1	2.6	0	0	0
5-6	0.77	0.08	0.1	0.3	0.2	0.1	5.3	0.2	1.3	1.0	1.6	0.1	3.0	0	0	0
6-7	0.90	0.12	0.3	0.5	0.1	0.3	7.1	0.2	1.2	1.3	2.2	0.1	3.1	0	0	0
7-8	1.30	0.15	0.6	0.5	0.2	0.4	9.7	0.3	0.9	1.6	4.4	0.1	4.5	0.1	0	0
8-9	1.84	0.23	0.6	0.5	0.2	...	14.4	2.9	1.3	1.6	6.3	0.1	5.6	0.1	0	0
9-10	2.40	0.43	0.3	0.1	0.2	...	19.3	1.8	2.1	2.8	6.7	0.1	9.1	0.2	0	0
10-11	0.71	0.53	0.1	0.2	0.1	...	5.4	3.9	2.7	3.3	0.7	0.4	1.7	0.1	0	0
11-12	0.54	0.56	0.1	0.1	0.1	...	4.4	3.7	2.3	3.7	0.6	0.4	1.4	0.1	0	0
12-13	0.53	0.53	0.2	0.2	0.2	...	4.2	3.4	2.3	3.0	1.0	0.6	1.3	0.2	0	0
13-14	0.55	0.49	0.4	0.1	0.1	...	6.0	3.5	1.8	3.0	2.2	0.5	3.0	0.2	0	0
14-15	0.57	0.50	0.3	0.1	0.2	...	4.2	3.7	2.2	3.1	1.3	0.6	1.4	0.2	0	0
15-16	0.55	0.54	0.3	0.2	0.2	...	4.2	3.0	2.0	3.1	0.9	0.6	1.3	0.2	0	0

TABLE 15

DISTRIBUTION OF SALT IN A SURFACE FOOT OF WOODROW SILTY CLAY LOAM SOIL IN INCREMENTS OF 1/10 FOOT, 1-5 AQUEOUS EXTRACT.

Depth	Electrical Conductivity at 25°C	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3
feet	millimhos/cm	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l	m.e./l
Salt crust*	....	....	...	...	...	...	.....	...	...
.0- .1	28.9	42.1	1.0	313	2.1	1.8	202	157	0.4
.1- .2	27.3	26.6	1.4	305	1.5	1.0	154	180	0.2
.2- .3	23.4	21.1	1.3	245	1.4	1.0	82.1	182	0.2
.3- .4	23.4	27.5	1.4	230	2.0	1.0	89.2	170	0.2
.4- .5	27.3	29.4	2.3	274	2.7	0.9	99.6	211	0.3
.5- .6	27.3	11.9	2.3	277	2.3	0.9	82.7	211	0.2
.6- .7	19.6	4.5	1.7	201	1.6	1.1	53.9	153	0.2
.7- .8	15.3	3.2	1.5	155	1.4	1.1	42.8	118	0.2
.8- .9	17.2	4.6	1.3	177	1.4	1.8	50.6	134	1.1
.9-1.0	16.4	3.8	1.8	169	1.2	1.2	46.7	124	0.2

* A salt crust of approximately 1/8" thickness covered the ground. The percentage composition of this salt was as follows:
Ca. 0.15, Mg. Tr., Na. 38.2, K. 0.10, CO_3 0.34, SO_4 5.38, Cl. 54.6, NO_3 0.31.

TABLE 16

AVERAGE RATE OF DROP (INFILTRATION PLUS EVAPORATION) IN INCHES PER DAY FOR PONDS A1, A2, A3, A4, B1, B2, B3, B4, AT TRACT 5.

Interval				Rate
From		To		
Date	Hour	Date	Hour	Inches per day
11-25-38	3:25 p	11-29-38	10:20 a	0.142
11-29-38	10:20 a	12- 1-38	7:25 a	0.109
12- 1-38	7:25 a	12- 3-38	10:30 a	0.192
12- 3-38	10:30 a	12- 5-38	10:30 a	0.138
12- 5-38	10:30 a	12- 7-38	10:30 a	0.144
12- 7-38	10:30 a	12- 9-38	10:30 a	0.150
12- 9-38	10:30 a	12-11-38	12:00 n	0.109
	Rain - intermittent			
12-1938	11:00	12-21-38	2:30 p	0.074
	Rain			
12-23-38	12:00 n	12-28-38	11:00 a	0.167
12-28-38	11:00 a	12-30-38	11:45 a	0.095
12-30-38	11:45 a	1- 1-39	12:00 n	0.107
1- 1-39	12:00 n	1- 6-39	11:00 a	0.056
1- 6-39	11:00 p	1-12-39	4:00 p	0.031
1-12-39	4:00 p	1-19-39	12:00 n	0.114

TABLE 17

TRACT NO. 5, 1938

CHEMICAL COMPOSITION OF 1-5 AQUEOUS EXTRACT FROM COMPOSITED SOIL SAMPLES TAKEN ADJACENT TO (B) AND IN FLOODED PLOTS (A).

Depth	Electrical Conductivity at 25°C		Ca		Mg		Na		CO_3 + HCO_3		SO_4		Cl		NO_3	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
feet	millimhos/cm		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e./l		m.e/l	
0-1	9.27	11.33	3.47	3.5	0.52	1.1	89.6	107.4	1.13	1.8	29.64	40.0	62.5	68.4	0.31	0.1
1-2	5.99	3.61	0.32	0.4	0.10	0.5	56.9	27.8	2.34	2.3	15.57	6.2	39.4	20.9	0.15	0
2-3	4.35	1.51	0.05	0.2	0	0.2	41.5	11.6	1.49	1.7	11.44	2.6	28.4	7.7	0.13	0
3-4	4.50	1.55	0.10	0.2	0.37	0.1	40.2	11.0	1.49	0.1	9.28	4.7	29.6	6.5	0.15	0
4-5	1.85	1.32	0.02	0.1	0.11	0.2	15.50	9.6	1.09	1.5	4.09	4.2	10.20	5.2	0.11	0
5-6	1.41	0.54	0.27	0.1	0.27	0.3	11.53	4.5	0.69	1.3	3.37	1.5	7.95	1.7	0.05	0
6-7	1.46	0.59	0.20	0.1	0.15	0.2	12.86	5.9	3.11	4.5	3.20	0.2	7.15	1.3	0.05	0
7-8	1.27	0.78	0.45	0.1	0.20	0.1	10.94	7.3	3.15	4.0	2.23	0.2	6.08	2.5	0.06	0
8-9	1.11	0.53	0.17	0.1	0.45	0.1	9.37	5.3	0.81	3.8	3.05	0.1	5.90	1.6	0.06	0

Infiltration rates on the plots were established by periodic hook gage readings of the water surface, with computations being made to establish the average rate in each interval between readings. In Figure 4, the medium weight vertical lines represent the time readings were made, and the heavy horizontal lines represent average rates for the intervening periods. The last reading of any irrigation and the first reading following the next irrigation are connected by light lines. There was frequently some recovery in rate with each irrigation, depending largely upon the time the plots dried out between irrigations, but such recovery did not approach the initial rates of the first irrigation of each plot.

Some data have been obtained on the macropore size distribution of surface soil from Tract 1b and Tract 5 (unirrigated soil). These data, summarized in Table 18, do not show any inherent physical characteristic that might preclude satisfactory agricultural usage if the soil were drained and irrigated with a water of lower sodium percentage.

TABLE 18

MACROPOROSITY FOR SURFACE FOOT OF SOILS OF TRACTS 1b AND 5.

Location	Macroporosity §	Apparent specific gravity
	per cent	
Tract 1b*	12.9	1.23
Tract 1b†	8.7	1.19
Tract 5‡	16.6	1.07

*Manured and flood-irrigated area in date planting.
†Non-fertilized adjacent irrigation ditch.
‡Unirrigated area.
§Macroporosity assumed to equal volume of pores drained when the tension of the soil water is increased from 0 to 40 cm. of water.

Laboratory studies of leaching

Approximately 800 grams of air-dry soil from the surface half-inch of Tract 1 were placed in each of six split case tubes 15 inches long and about 2 1/8" in diameter. The bottoms of the tubes were cone-shaped and perforated. The soil filled the tubes to within about 3 inches of the top. Two sets of 3 tubes each were equipped with constant water level devices. To one set water from well 1, of Table 5, a high sodium water was applied; to the other, Colorado River water. During the first few days the amount of water percolating through the soil column was approximately the same for both sets, but at the end of two months the ratio was approximately 2½ to 1 in favor of the Colorado River water. The percolation rates at the end of the run were in all cases much lower than the initial rates.

Base exchange studies made after the runs were completed showed an average sodium percentage of 56 for the soils receiving high sodium water, and 36 per cent for those receiving the Colorado River water.

Under field conditions, with alternate wetting and drying of the soil combined with the effect of plants growing on the soil, we would expect that the percolation ratio would, in time, be much more favorable to Colorado River water than is indicated by these tests.

Flushing

Data in Tables 9 to 17 indicate that a relatively high percentage of salines are found on or near the soil surface. The feasibility of salt removal from the soil surface by flushing was investigated and found to have promise. Although this method is more limited in its application than the leaching method it does permit the direct removal of salines without having them pass through the soil profile.

In July, 1938, samples of spill water from the end of a basin-irrigated date orchard near Tract 1 (b) were collected at half hour intervals. The electrical conductivity measurements of these samples are reported below. The results are only qualitative since run-off was not measured. The conductivity of the irrigation water as it entered the orchard was about 250 micromhos/cm.

Hours after run-off started	Electrical Conductivity at 25°C of surface drainage	
	1st Irrigation	2nd Irrigation
hours	Micromhos/cm	Micromhos/cm
0	6160	10590
½	5070	8260
1	5660	7980
1½	3990	7610

In April, 1939, an area was selected adjacent to the unirrigated area of Tract 5, and strip checks of approximately one-hundredth of an acre were developed. The Spring winds, which are common to the Valley, had blown away some of the salt crust that had been especially noticeable earlier in the year.

Soil for the levees was borrowed from outside the check so as not to remove the salt crust from the soil within the check. Water-measuring flumes were installed at the entrance and exit of the checks, and water samples were collected at intervals throughout the run. Electrical conductivity determinations were made on water samples, and in a number of cases total solids were determined. The first effluent was very saline, as indicated in Figure 6, (page 29). The first run was made on April 6, 1939. On April 27, another test was run. Prior to the second run, the soil surface was white with salts, mainly sodium chloride. The first water to pass from the check was extremely saline, its salt content being in excess of 40,000 p.p.m. The salt concentration dropped very rapidly as water passed over the soil.

These data indicate that with the wastage of relatively small amounts of water large amounts of salt can be removed directly from the surface of the soil. This offers a method of salt removal, especially during the early stage of reclamation. It is not a complete method of salt removal, however. Attention should be called to the fact that flushing accomplished more, in each case, in the second irrigation than in the first. Some upward capillary movement of salt in the top inch or two during the intervening period appears to be indicated.

Reclamation and Drainage

The conclusion of these investigations is that most of the highly saline soils of the Coachella and Indio series, other than the very fine Indio clays, can be reclaimed and continuously utilized provided that they are properly irrigated with Colorado River water, and further, provided that the soils are adequately drained. The profitable use of the soils of the Woodrow series for general crops is questionable. Reclamation methods might include both flushing and leaching.

The chief problems associated with the increase in irrigated area will concern the prevention of a general high water table and, more locally, overcoming difficulties attributable to perched water tables above abrupt changes in soil texture. In regard to the prevention of a general high water table, emphasis must be placed on the maintenance of pumping. Additional pumping from wells located above the area to be served with imported gravity water would cause lowering of piezometric levels below, and so help to relieve the drainage problems of the lower trough.

Percolation from gravity-irrigated areas should be of considerable magnitude, and should necessitate extensive drainage measures in order to utilize the lands of the lower trough, both those which are now saline and those which are under cultivation. Thus there are two phases of the drainage problem:

a. Maintenance of the normal ground waters at reasonably low levels by pumping for irrigation.

b. Removal of relatively shallow perched waters originating in the irrigation of upstream or overlying lands.

Much of the latter water will undoubtedly be too saline for further utilization.

Considerable stratification, with abrupt textural changes, is the rule with Coachella Valley soils. This condition adversely affects the permeability of the profile, and many perched water tables have been observed (11) above such changes in texture. Such perched water tables, although essentially temporary in nature, will affect drainage when close to the surface. Throughout most of the Valley the strata closely parallel the ground surface, and are rather discontinuous as evidenced by soil sampling to 18 food depth and by comparison of well logs to considerable depth. The least permeable and most continuous strata are found near Salton Sea. Such layers, when close to the surface, may impede reclamation.

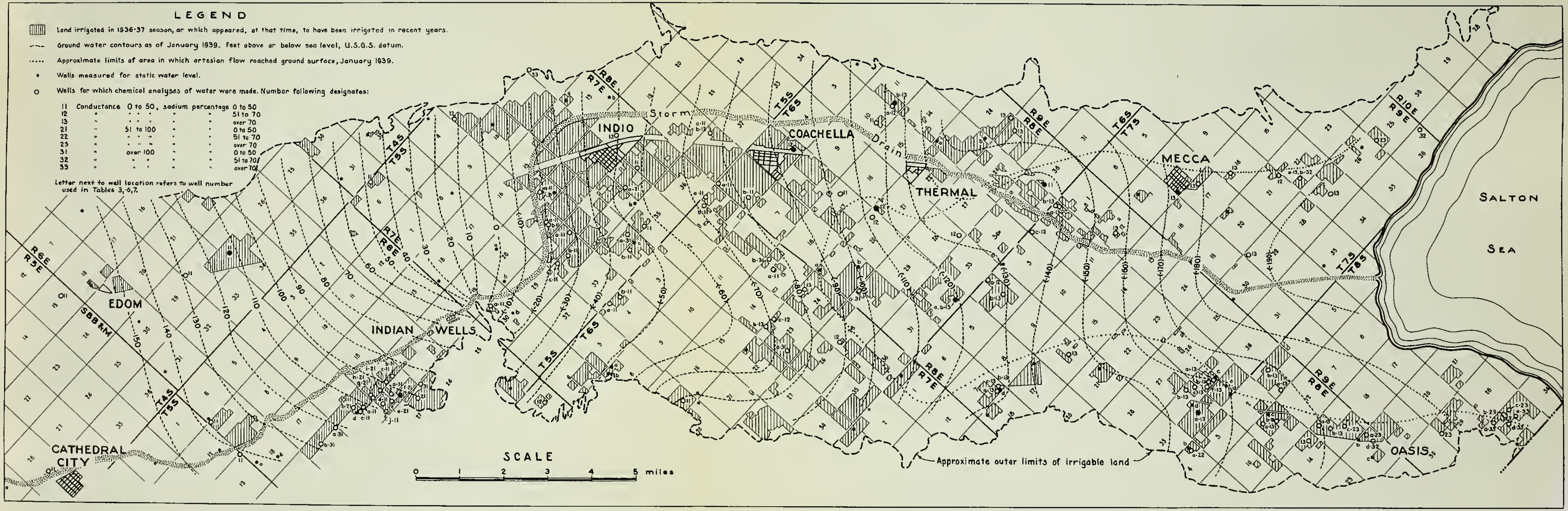

Fig. 1. Map of a portion of Coachella Valley, California, showing ground water contours as of January, 1939, the 1936-37 irrigated areas, wells measured for static water level, and wells for which chemical analyses of the water were made (together with key numbers indicating the type of water).

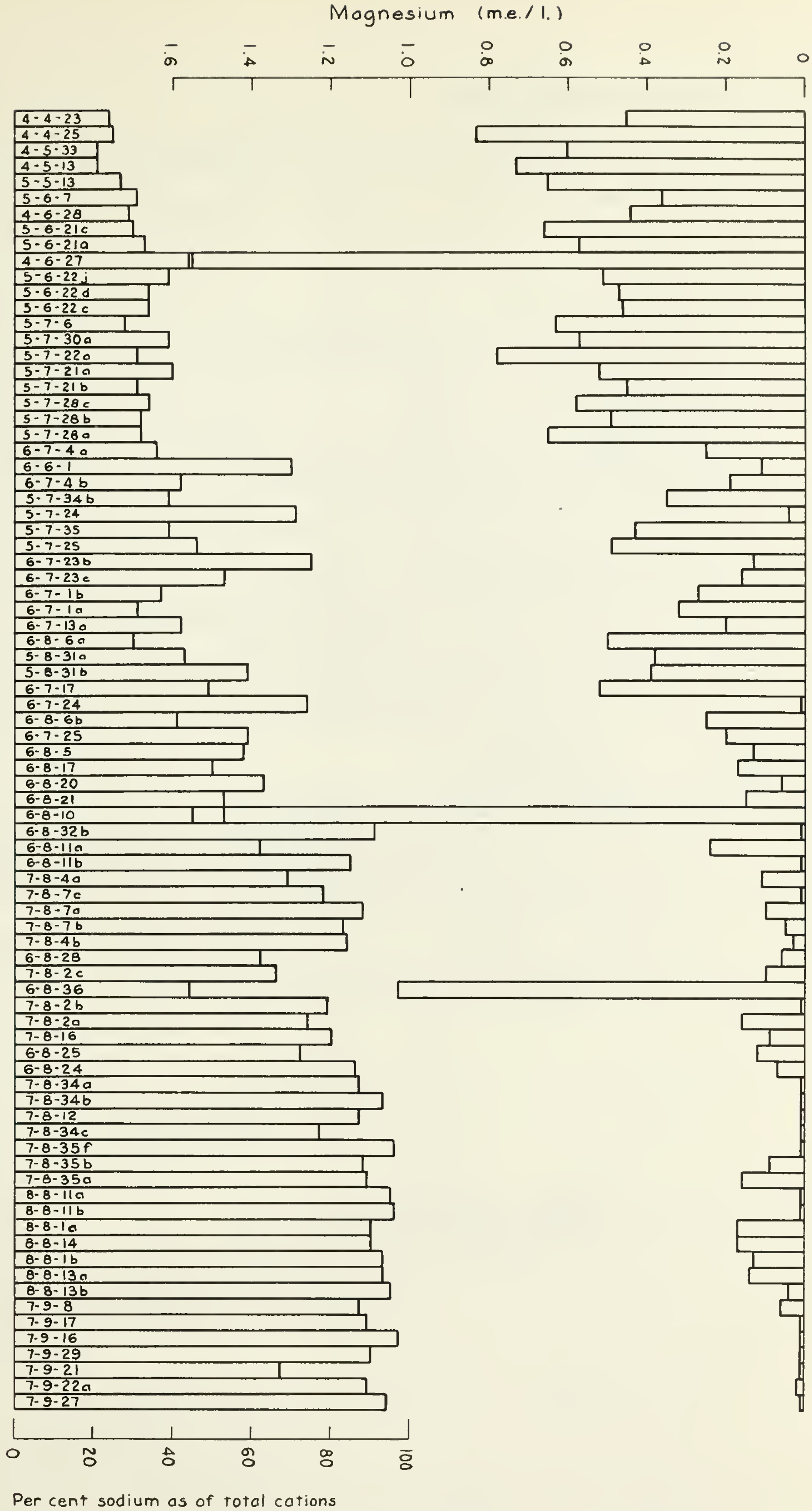

Fig. 2. Chart showing per cent sodium and magnesium content of water for all wells from which samples were obtained for analysis which had a conductance of 50 or less, progressing down the valley (from left to right of Figure 1).

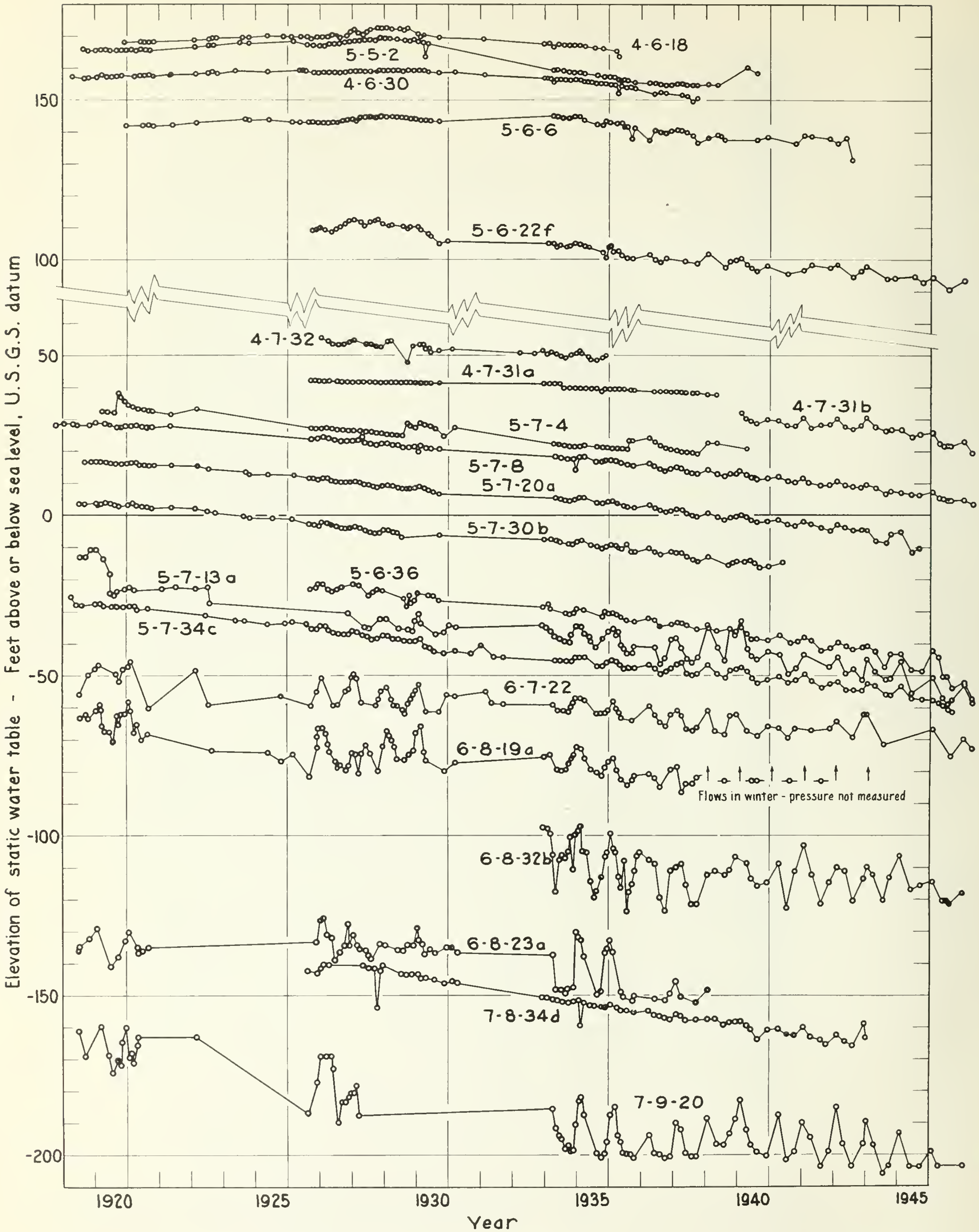

Fig. 3. Ground water fluctuations for key wells selected on the basis of geographical distribution and length of record.

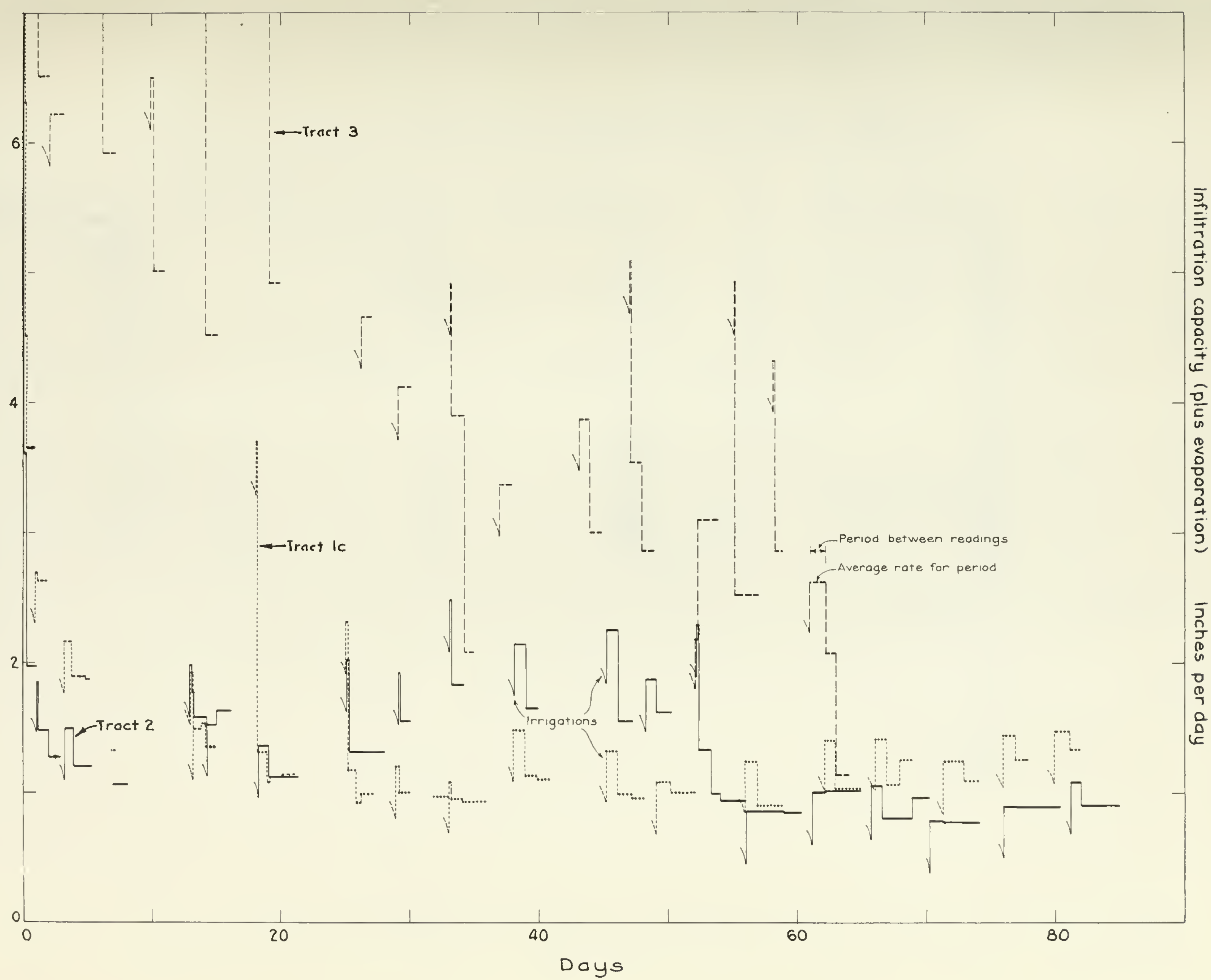

Fig. 4. Infiltration records for leaching plots, 1939. Heavy horizontal line indicates average rate for period between vertical lines. Initial rates for each plot were high, and are not shown on the chart.

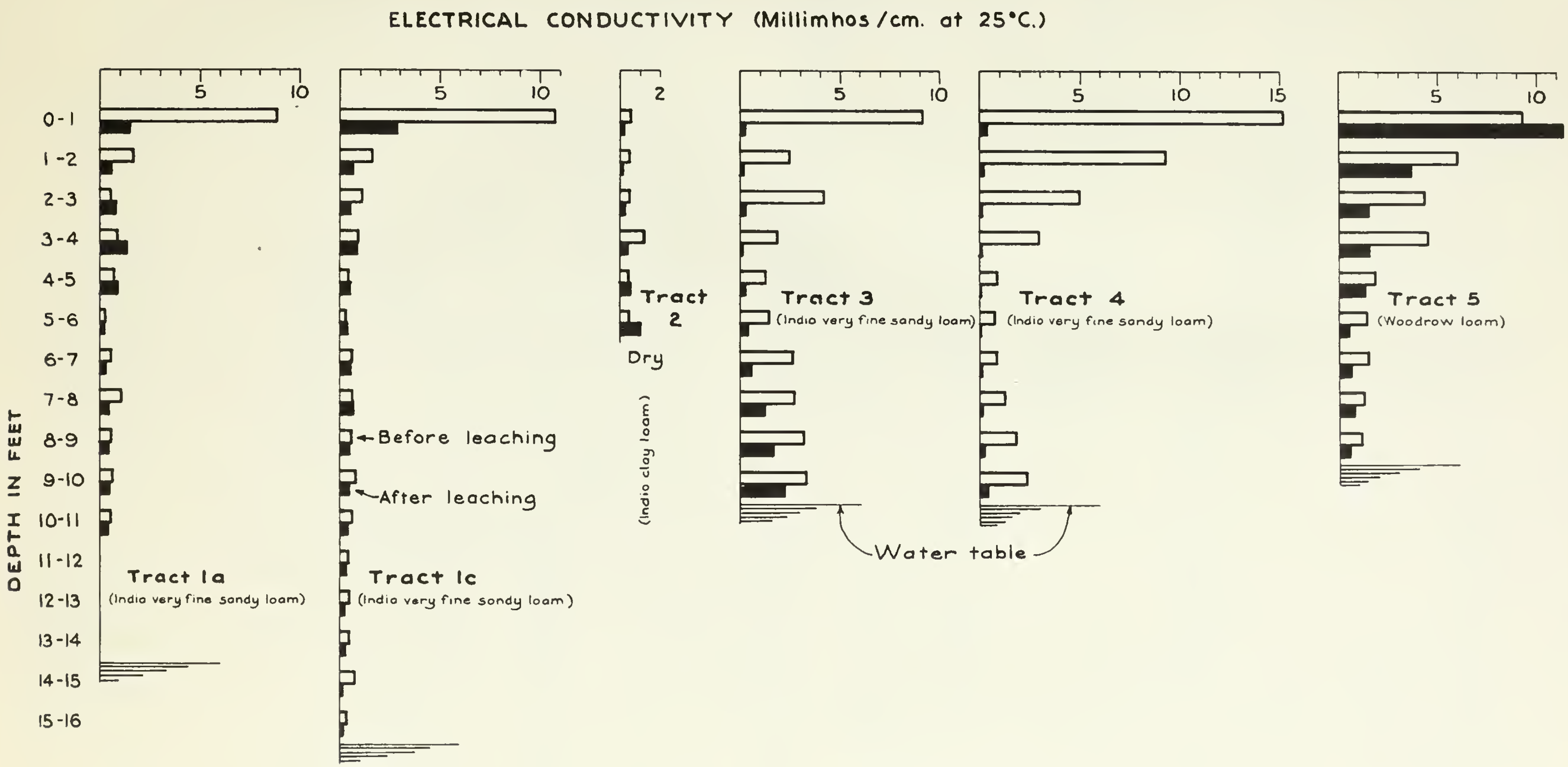

Fig. 5. Electrical conductivity of soil extracts (5 water to 1 soil) between surface and water table before and after leaching. Coachella Valley plots, 1938-39. Open bar, before leaching; solid bar, after leaching.

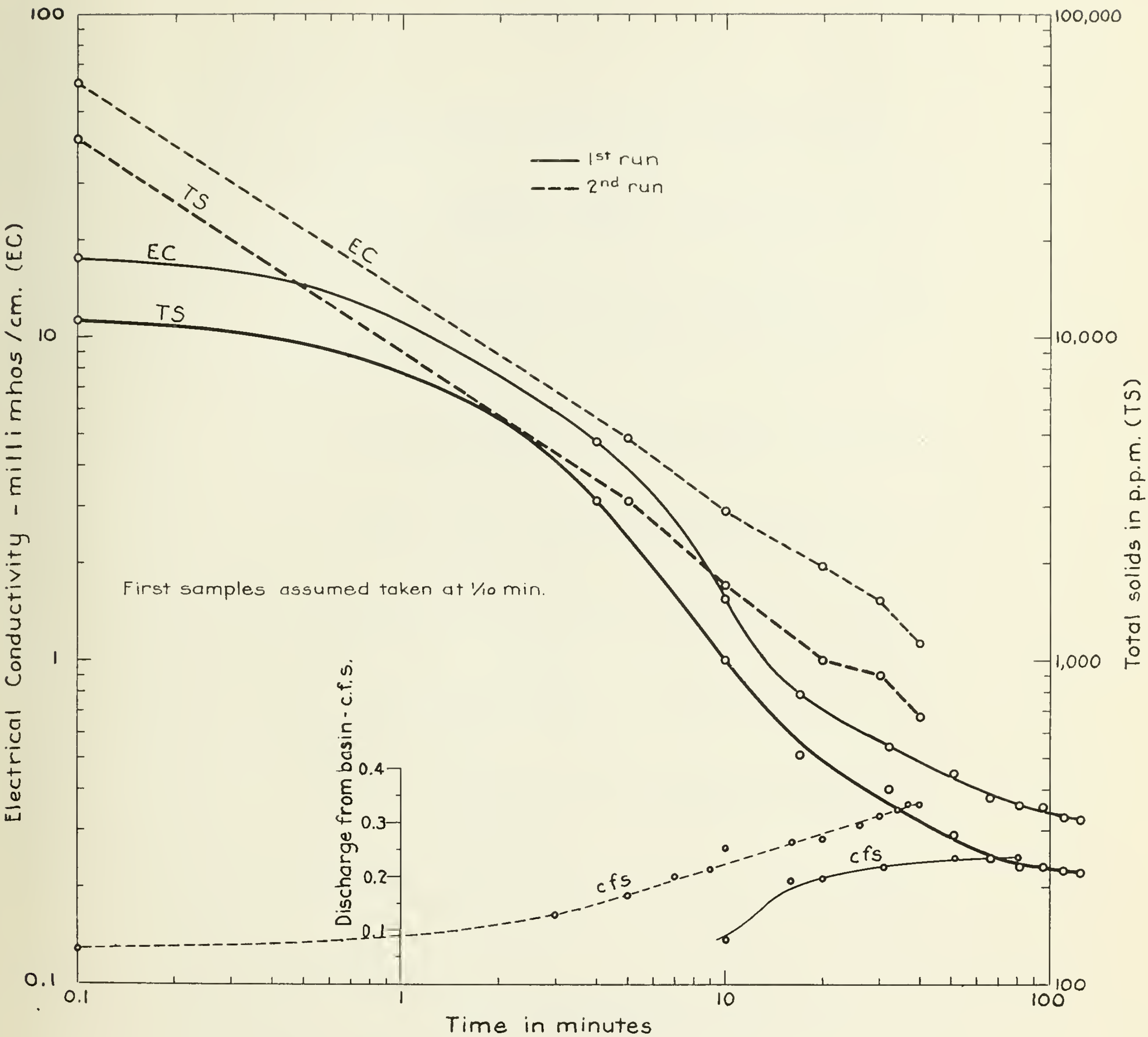

Fig. 6. Curves of discharge, electrical conductivity and total solids for effluent from flush-- ing plot, runs of April 6 and 27, 1939, plotted logarithmically.

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